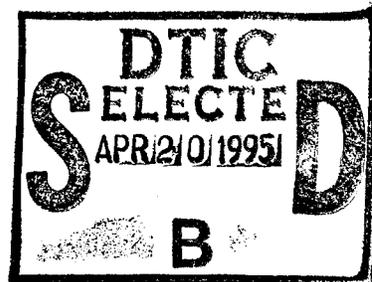


**THE IMPACT OF THE HUMAN DIMENSION ON
A THREE-MAN-CREW TANK**

**A Monograph
by**

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Armor**



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ABSTRACT:

THE IMPACT OF THE HUMAN DIMENSION ON A THREE-MAN-CREW TANK

Nearly every armor force in the world has fielded, is fielding, or is designing a 3-man tank. This paper deliberately steps away from the purely technical argument associated with this effort. It seeks to find out if the United States Army is considering the human dimension and ergonomic factors during the design of a future 3-man-crew tank to adequately address the problems associated with extended operations. The paper begins with an extensive examination of the loader's duties on a tank within the context of extended operations. It examines duties on leader tanks, vehicle security, crew member replacement, and degraded operations to establish a contextual understanding of human dimension issues associated with continuous operations. The second chapter examines the army's MANPRINT effort, the former Soviet Union's human dimension integration effort, compares the Armored Gun System SMMP and TEMP, and concludes with an examination of successful soldier-in-the-loop testing using the MWTB and UCOFT. The third chapter addresses emerging technologies likely to be incorporated into the future main battle tanks, again within the context of continuous operations. The study concludes by introducing a fightability standard for emerging technologies and makes recommendations for improving early user involvement in the development of systems.

SCHOOL OF ADVANCED MILITARY STUDIES

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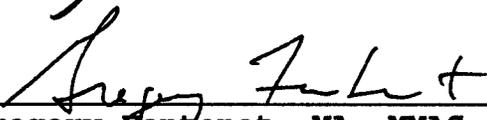
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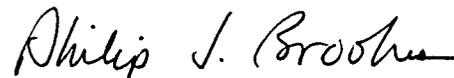
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I. INTRODUCTION

Much of the impetus to reduce American tank crews from four to three members is design driven. Future tank design problems revolve around the need for a lighter vehicle with more crew protection and a lower profile to decrease its signature on the battlefield. The M1A1 Abrams, our current main battle tank, is at the upper end of the scale for allowable vehicle weight. It is critical, in light of America's current power projection orientation, that a future tank be light enough to be air transported. Adding armor for crew protection to the current main battle tank basic design makes the vehicle too heavy to be air transported. Many complain that the Abrams presents too large a target on the battlefield. A new design could situate the crew lower in the hull and thereby allow a lower profile for the vehicle. This would require eliminating a crew member due to reduced space and would provide for needed additional armor protection without exceeding weight limitations.

In addition to vehicle weight, personnel costs are often cited as a driving force behind the need for crew size reduction. However, a 1985 study priced the 3-man version of the Armored Gun System (AGS) at \$100 million more over twenty years than the 4-man crew option.¹ If future designs offer similar "savings," then their economic viability will be called into question. There is also a legitimate concern over total army end strength. Reducing the crew size does provide a slight improvement in terms of numbers of troops required. However, if crew reductions in the army's "tooth" (combat troops) result in merely shifting crewmen to the "tail" (logistics and rear area troops), then no manpower savings are actually realized. It is arguable that adding to the support tail is less desirable than maintaining current combat troop numbers.

Ergonomic issues inherent in crew reduction do not receive the same research emphasis as do other technology issues. Significant resources are being spent on other

armored vehicle modernization projects. These efforts include autoloader technology, anti-missile technology, artificial intelligence, acoustic and millimeter wave sensors, NBC warning systems and stealth technology. The trend toward solving human engineering problems is improving, but most projects are in infancy.

Our most glaring human engineering shortcomings are not purely man-machine interface problems. They include considerations regarding leader tanks, vehicle repair and maintenance, vehicle security requirements, degraded mode operations and continuous operations in an extended field environment. Two studies of note, "Is a Turretless Tank a Viable Option for the United States Army?" by Gary L. Moore² and the 1991 RAND Corporation study, An Exploration of Integrated Ground Weapons Concepts for Armor/Anti-Armor Missions, concluded that the 3-man tank is a viable option and the design of choice for our future main battle tank. Both studies approached the problem from almost a purely technical standpoint. To quote the RAND study:

"Our designs have not directly addressed the problems of extended engagements in which crews may have to fight for days at a time. Attention needs to be given to scenarios in which crews may be rotated, 24-hour watch is maintained, and sleep, rationing and hygiene requirements are met."³

This is indicative of our traditional R&D efforts to design new equipment. Technology problems are resourced and often addressed to the nth degree; human engineering factors are largely left for field tests and validation. At that point in the development cycle, so much money is invested that it is almost unthinkable to kill a system because of crew issues. Additional dollars are then required to fix problems at great expense. If the human engineering issues were addressed earlier in the development process, R&D money could be saved, overall system costs lowered, and, as important, we would develop systems which require fewer modifications and better serve the soldiers who operate them. Training energy could be directed toward exploiting the use of the system instead of learning to live with a flawed system.

Nearly every armor force in the world has fielded, is fielding, or is designing a 3-man tank. The Soviets have had 3-man tanks since fielding the T-64 Medium Tank in 1972. All subsequent models have been 3-man tanks. The French are currently fielding their version, the Leclerc. The Japanese are developing a 120 mm gun-equipped Type 90 tank.⁴ The United States will conduct user tests on the AGS, a 3-man light armored cavalry vehicle, in January 1995. Our army's future main battle tank is envisioned by many as a 3-man tank. The U.S. is also studying a 2-man tank design.

A critical assumption in discussing the design of the army's next main battle tank is that the current main gun configuration will be retained. Possible alternatives for future designs could include directed energy and liquid propellant technology, but those technologies are too new and will likely not be incorporated in tank designs before 2015 or 2020. Fielding those technologies will require a completely new design.

A danger in considering only technological improvements is fixation on the technical aspects of design. This leads to a circular argument which may convince one of the requirement to reduce crews based on technology alone. Technologists assert that future enemy tanks will have thicker armor and larger calibre guns with greater armor piercing capability. They further posit that our future tanks can not be any heavier or larger than the current design. From this, one concludes we must add armor to provide more protection and make the main gun round larger to gain greater armor penetration capability and increased range. This requires adding an autoloader and reducing the crew size. Reducing the size of the crew reduces the area which must be protected, therefore achieving the necessary level of protection without adding weight.

This paper deliberately steps away from the purely technical argument. It seeks to find out if the United States Army is considering the human dimension and ergonomic factors during the design of a future 3-man-crew tank to adequately address the problems associated with extended operations.

II. HUMAN DIMENSION

The army doctrinally recognizes that operating in a continuous combat environment adversely affects soldier performance. This chapter examines human dimension issues associated with armor operations within the context of continuous operations. **Continuous operations (CONOPS)** involve continuous land combat with some opportunity for sleep although it may be brief or fragmented. **Sustained operations (SUSOPS)** are continuous land combat with no opportunity for sleep.⁵ Within any CONOPS there are likely to be periods of SUSOPS.⁶ The combat environment also involves **around-the-clock operations** which do not fit the strict definition of CONOPS due to a lack of intensity and for which there is no doctrinal term. For example, in a location, such as an assembly area, contact with the enemy is not usually imminent, but is possible. This situation requires implementing an effective sleep plan to minimize the effects of sleep deprivation and enable a unit to remain effective for extended periods of time.⁷

The human dimension involves consideration of situations which place added strain on the crew. An analysis of the division of labor for armor crews, especially the duties of the loader, reveals the need for special consideration of the circumstances associated with around-the-clock operations, CONOPS, and SUSOPS. Examination of leader tanks, security, crew member replacement and degraded operations will establish a contextual understanding of human dimension issues associated with continuous operations.

The US Army Tank Automotive Command (TACOM) established a baseline tank crew task list in the 1987 report, "Main Battle Tank Crew Task Analysis." It was an analysis of the four-man crew configuration and detailed the duties and responsibilities of each crewman in the Abrams-series tank. The report identified the tasks for the loader,

driver, gunner, tank commander (TC), and TCs serving as the Platoon Leader/Platoon Sergeant.⁸ If armor crew size is reduced, the duties and responsibilities of the lost crewman do not simply disappear. Duties not compensated for by technological innovation or mechanization shift to the remaining crew members. Tank developers can use the report to evaluate the extent to which an emerging technology compensates for the loss of a crewman.

The loader is often identified as the crew member most readily replaced through technological innovation. The Soviet Union was the first nation to field autoloader-equipped tanks in 1972.⁹ The United States' experimental MBT-70 (main battle tank) program in the 1970s was to be equipped with an autoloader. However, the U.S. eventually fielded the M1 Abrams, a conventional four-man crew tank. The army's future main battle tank, Tank 1080 (or Block III), currently under development, is envisioned as a three-man tank.

Evaluating the validity of replacing the loader with an autoloader requires an understanding of all loader responsibilities within the context of the operating environment. The following table shows the areas of responsibility for each crew position. A complete list of loader tasks is at Appendix A.

<u>Loader</u>	<u>Driver</u>	<u>Gunner</u>	<u>Tank Commander</u>
Operational Tasks	Operational Tasks	Operational Tasks	Operational Tasks
Main Weapon Firing		Main Weapon Firing	Main Weapon Firing
Secondary Armament		Secondary Armament	Secondary Armament
Ammunition	Ammunition	Ammunition	Ammunition
Handling Tasks	Handling Tasks	Handling Tasks	Handling Tasks
Maintenance Tasks	Maintenance Tasks	Maintenance Tasks	Maintenance Tasks
Tactical Tasks	Tactical Tasks	Tactical Tasks	Tactical Tasks
Observation	Observation	Observation	Observation
Communication	Communication	Communication	Communication (C ²)
Security	Security	Security	Security
Additional Tasks	Additional Tasks	Additional Tasks	Additional Tasks
		Fire Control	Fire Control
		Engagement	Engagement
			Navigation

From "Main Battle Tank Crew Task Analysis"¹⁰

An analysis of the loader's tasks in each area of responsibility follows. Tasks may be eliminated through automation, modified by the application of technology or shifted to other crewmen. The analysis assumes the following: if automation on the tank requires the redesign and fielding of another system which is not a part of the tank, then automation can not be assured. Fielding new or redesigned materiel in light of the current environment of constrained resources is unlikely. As an example, the army has not replaced it's primary recovery vehicle, the M88, despite a gross mismatch in towing power in relation to the weight of the M1 tank.

Operational Tasks

There are nine primary tasks related to the loader's operation of his station. Installing an autoloader completely eliminates only one, operate the elevation uncouple.¹¹ Automating the following three tasks does not add any significant responsibilities to the workloads of other crewmen:

- Reset circuit breakers in turret networks box
- Operate NBC system/turret blower motor
- Operate emergency engine shutoff.

Two others, prepare the loader's station for operation and power down and secure the loader's station, are largely eliminated with the exception of operation of the amplifier, installation and removal of antennas,¹² and stowing coaxial machine gun (coax) ammunition. The coax ammunition storage box holds 10,000, 7.62 mm rounds. The ammunition is packaged in 100-round links which must be connected by hand and then manually fed into the stowage box.¹³ To automate stow coaxial ammunition belt would require a redesign of 7.62 mm ammunition packaging, as other weapon systems use the ammunition. These and the following tasks must shift to other crewmen:

- Ground guide vehicle
- Assist refueling tank
- Assist in boresight operations

Refueling the tank is a task which some designers believe could be automated. To do so would require redesigning the fuel tanker. Fuel tankers currently dispense fuel manually to all vehicles through a hose and nozzle.

Main Weapon Firing Tasks

There are four main tasks in this area. Only loader's firing operations is eliminated by an autoloader. The others, loader's pre-fire operations, loader's misfire procedures and post-fire operations, can not be automated and must be assumed by other crewmen. Pre- and post-fire operations will largely become preventive maintenance, checks, and services (PMCS). Both tasks would be more manpower intensive than they are currently. An autoloader will be enclosed in a much smaller and presumably separate area. PMCS will be more complex as a result. The autoloader will be capable of clearing a misfired round; however, misfire procedures would be much more manpower intensive were the autoloader unable to correct the malfunction.

Secondary Armament Tasks

All but one task will be eliminated, if it is assumed an autoloader equipped tank will not have a loader's weapon.¹⁴ The task, load, clear and maintain grenade launchers will be assumed by another crewman as it cannot be automated.

Ammunition Handling Tasks

All four-man tank crewmen have this manpower intensive area of responsibility listed as one of their responsibilities. Removing the loader from the crew will increase the workload of the other crewmen. It currently takes three men about 20-25 minutes to break down, inspect and stow 40 rounds of 120 mm main gun ammunition. Rearming the tank with main gun ammunition could be automated; however, this involves the redesign and fielding of a new ammunition handling system.

Maintenance Tasks

This is another significant, manpower intensive area, the tasks for which must shift to other crewmen. None of the tasks under this heading could be eliminated.

Assist other crewmen as required is a rather benign sounding, catch-all task. It carries significant implications. Many components on the tank are very heavy and require two, and sometimes three, men to lift or install. While the gunner has replace thrown track as one of his tasks, it is impossible for him to perform it alone. There are numerous other components on the tank which require time-consuming, heavy manual labor to maintain or replace.

Richard Simpkin argues against a 4-man crew by noting that most heavy manual tasks are associated with replenishment and are done "when men other than crews themselves are available."¹⁵ Support personnel have been drastically cut during the last decade and are not available in sufficient numbers to be realistically expected to perform those tasks for the crew. Crewmen are expected to assist the mechanics in accomplishing their tasks. During maintenance, more often than not, the tank crewmen perform maintenance tasks. A mechanic supervises or inspects the work. This is necessary because the mechanic performs or supervises other work concurrently.

If sophisticated technologies are added, crew size is reduced, and the workload is merely shifted to support troops, then no manpower savings are actually realized. Increases in the tank unit's logistical requirements are counter productive. An increased reliance on support troops hinders the crew and unit's capability to sustain itself during extended operations.

Tactical Tasks

In this manpower intensive area there are fifteen tasks. Three, probe minefields, assists in NBC operations, and distribute range cards, could be accomplished or have the workload mitigated by technology applications. The mine plow and mine roller attachments currently in use have an attachment to defeat tilt-rod and magnetic mines. Sensors may be added which detect minefields as well. Distribution of range cards may occur through a distributed information network, such as the Intervehicular

Information System (IVIS).¹⁶ The loader cannot accomplish nine of the tasks alone. For each of those it is necessary for the loader "to assist. . ."

Each of the nine tasks doctrinally requires more than one crewman to accomplish. Eliminating the loader places a greater strain on the crew workload balance for these tasks. Not only must another crewman perform a task, but such tasks require at least two of the remaining crewman. This affects the task at hand and impacts crew rest schedules (discussed later) and other tasks which could be accomplished concurrently. Ralph Zumbro, a tank commander in Vietnam, expressed the point well.

"Armored units are always short of manpower, and everybody, including command NCOs and officers, was hauling and sweating. Those of the crews who were left with the tanks were setting tarps and making range cards, getting ready for the night."¹⁷

There are even more serious implications for three-man crews reduced by casualties, sickness or for other operational reasons. Three tasks are deliberately designed to take the loader away from the tank. Two, deliberate occupation recon and security team leader and assists in quartering party activities, routinely occur in the tactical environment. Reassigned to replace casualties as necessary bears more onerous implications. It will be discussed later when considering degraded operations.

Observation Tasks

There are four tasks in this area. All can be addressed to varying degrees by automation and technology applications. One note in the context of crew workload is important. The loader is usually assigned as the air guard and has an assigned sector of responsibility, approximately 180 degrees. Technology may well mitigate the workload shifted from these tasks to other crewmen through the use of sensor. Otherwise, it remains for either the tank commander or the gunner to cover the area no longer covered by the loader (the driver, because of his location on the tank, has a relatively fixed field of view), in addition to his current area of responsibility.

Communication Tasks

Two of the four tasks in this area may be automated. It is important to note that the army's radios are not integral components of any vehicle. They must be installed, removed and manually operated when they malfunction.¹⁸ That responsibility is currently the loader's. PMCS for the radio must be shifted to another crewman as well.

Radio watch (monitoring the radio) and monitor additional net on command tanks are actually two tasks performed on eight of fourteen tanks in a company. Those vehicles have dual radio net capability. Technology applications may allow a crewman to perform other tasks concurrently. Radio watch is normally performed by the crewman on air guard. Both tasks require cognitive energy and factor importantly into the crew workload.

Security Tasks

As with the observation tasks, technology positively impacts four of the six tasks in this area: emplace and retrieve mines, LP/OP,¹⁹ local security, and assists in providing 360 degree security during tactical operations. They normally require physical as well as cognitive effort. All six must be assumed by other crewmen despite any technology enhancements.

Additional Duties

Only assist in land navigation will be eliminated by technology. Provide driver relief as necessary and assist vehicle commander as necessary are doctrinal recognitions that other crewmen may not always be able to perform their primary responsibilities alone. For example, the most common reason for relieving the driver is fatigue. Technology may allow another crewman to more easily take-over driving using a redundant work station; however, this involves little more than switching crew responsibilities. The relieved driver must then perform the tasks of the crewman who is now driving. Assuming responsibility for other cognitive tasks is no relief at all. Having a fatigued crewman take over a critical task, such as scanning for enemy tanks,

may more severely degrade and endanger the tank/crew fighting system than were the tired driver to continue his job. Assisting the tank commander is much more complex. Even an inexperienced loader can aid in navigation, communication, threat recognition, fighting, even command and control.

Runner/messenger and assists in messing activities are examples of nebulous tasks. The skill might just as well be burn organic human waste. This example is not meant to be flippant. It is a real example of a very time consuming task soldiers daily performed during both Vietnam and DESERT STORM. The task gains import when one considers that the power projection United States Army is in the future more likely to be operating in austere environments. This is especially true of tank units. The listed tasks represent a myriad of jobs which soldiers perform every day in a combat environment. Many are not found even on an exhaustive crew task list such as the Main Battle Tank Crew Task List.

Additional Human Dimension Considerations

Every tank crewman in a combat environment is a busy soldier. Contrary to Simpkin's assertion, each crewman in a four-man crew does not have a single-skill task. A crewman does not just hit the target, drive the tank or load the gun.²⁰ Viewing the loader as performing only one function is a rationalization; it simplifies the argument to replace him with an autoloader. A similar analysis of the other three crewman's responsibilities would reveal equal if not greater complexity in their jobs. Such nuances are often overlooked by individuals unfamiliar with tactical operations.

If a crewman is removed, each function must be completely replaced by a technology enhancement or diverted to another crewman. Simpkin and others assert that the size of the crew should be set at the minimum needed to operate the tank in order to optimize tanks for performance²¹ Martin Van Creveld argues effectively against such a trend.

"Rather, in armed conflict no success is possible - or even conceivable - which is not grounded in an ability to tolerate uncertainty, cope with it, and make use of it. . . to be capable of coping with the uncertainty that is the result of enemy action and, as such, inherent in war - in that case a certain amount of redundancy, slack, and waste must not only be tolerated but *deliberately* built in [emphasis added]. . . there are any number of occasions when military effectiveness is not only compatible with diminished efficiency but positively demands it be sacrificed."²²

The tenets of U.S. Army operations doctrine are initiative, agility, depth, synchronization and versatility.²³ The weapons we employ must complement those tenets. Technology will enhance our capabilities, but it is as important not to fine-tune systems to the point that technology limits them as well. If weapons are too optimized, new vulnerabilities may emerge which simplify rather than complicate the enemy's job. Systems may become so sophisticated that only by highly trained soldiers can operate them. This might restrict crewmen from being able to switch between positions. It may also affect the ability to replace wounded or killed crewmen.

Leader Tanks

Eight tanks in a tank company and 34 out of 58 total tanks in a battalion are leader tanks.²⁴ All tank commanders ". . . [are required] to guide the tank, talk on the radio, scan for and acquire targets, decide when and how to engage them - and to verbalize [their] intentions in the shape of orders and briefings."²⁵ On a leader tank the job is even more complex. The leader must direct and coordinate his unit's actions, report his situation, and integrate the actions of his unit with those of other units, in addition to directing the operation of his own tank. He currently accomplishes all of this using only a map and a radio. Entire manuals are devoted to the doctrine and tactics of unit employment for each echelon.²⁶

The army devoted the Battle Command Battle Lab at Ft. Leavenworth, Kansas, to addressing the problems associated with the complexities of command and control. The aim of much of the army's digitization effort is to make the leader a more effective and efficient commander.

Technology enhancements do not come without a price. The Armor School is developing the Commander's Independent Thermal Viewer (CITV) and IVIS to assist tank commanders and leaders in accomplishing their missions. Many of the processes now performed manually will be automated. Each new piece of equipment adds a new set of manual and cognitive skills to the tank commander's workload. Some tasks will be consolidated or replaced; however, new ones will be added. As the German general Hans von Seeckt noted in 1930, "The greater the advance of technical science, . . . the higher will be the demand it makes on the soldier who manipulates the technical aids."²⁷

The Advanced Warfighting Experiment (AWE) 94-07, OPERATION DESERT HAMMER VI, was conducted in April 1994 to test "the hypothesis that advanced electronics capable of moving information rapidly around the battlefield will result in significant increases in lethality, survivability, and tempo."²⁸ The final report on the exercise noted,

"For the purposes of this AWE, the leaders were given the digital equipment to operate. . . TCs felt that they were overloaded with more tasks. Participants said that digital technology requires more work of commanders. . . Several felt that the loader and gunner must pick up more digital responsibility. It was reported that there was more work for gunners (i.e., making up for the commander's workload). Some felt that the driver will have to operate more on his own. Some said their solution was that the loader acted as TC while the TC operated the IVIS."^{29,30}

The implications are clear, ". . . it will be necessary to readjust the workload as digital technology is adopted."³¹ When one combines these findings from a four-man crew with the elimination of a crewman, the impact on the workload distribution and the potential for overloading the crew is substantial.

On a related topic, the leader spends a considerable amount of his time away from his vehicle in addition to all his duties on the tank. He inspects vehicles and fighting positions, conducts rehearsals, prepares and issues orders, attends rehearsals, receives

orders, and conducts physical and personal reconnaissance of future positions and battlefields. BG Maggart noted that digitization increased the time available for planning at company team and platoon levels by nearly 30 percent over non-digitized units.³² This is an important benefit of digitization; however, it will not relieve the leader of the necessity to be away from his vehicle for substantial amounts of time.

Each crewman's workload will increase on a reduced-crew vehicle. More significantly, the crew must complete all essential tasks with only two men whenever the leader is away. The analysis of the loader's tasks revealed a number of tasks not related to the operation of the tank itself (security, radio watch, and maintenance, etc.), which he must perform to accomplish the mission in combat. The loader (and the other crewmen) must complete the tasks with or without the leader present. This is taxing for a four-man crew. It may well be impossible for a three-man crew.

Security

Reducing the crew significantly impacts vehicle security. It is illuminating to consider a seemingly simple issue such as the acceptable minimum number of soldiers which must be awake for security.³³ Generally, two soldiers stay awake better and are more alert than if only one soldier is awake. However, if normal operations and maintenance require more than two soldiers, sleep plans will be greatly affected and the duration that fatigued crews can safely function during extended operations seriously impacted.

A number of experts assert there will be other non-armor soldiers available for security because the modern combat unit will operate in a combined arms team.³⁴ "Surveillance and guard problems can be solved by sufficiently close integration of tanks and armored infantry".³⁵ The assertion is indisputable, its application is not. This argument essentially involves a zero-sum gain, trading armor crewmen for infantrymen. Units may not always operate as combined arms. Doctrinally, we task organize troops for each mission by considering the mission, enemy, terrain, friendly

troops available, and time (METT-T). Infantry and armor units have unique capabilities and functions in certain terrain and against certain enemy. Armor and infantry units employed together may have separate sectors of responsibility which overlap; however, infantry is not normally assigned the mission of guarding the same sector so that the armor unit can sleep. The infantry does not solely provide for security of the armor, though they may enhance it. During around-the-clock operations, a three-man crew sleep rotation is a less pronounced problem. During CONOPS and SUSOPS fatigue is a more acute problem. CONOPS and SUSOPS do not occur in isolation. Around-the-clock operations often precede and succeed them. The effects of stress, fear, and some loss of sleep will have degraded crew efficiency as well. When all members of a crew operate for an extended period of time, as in the 100 hours of DESERT STORM, fatigue and its effect on security become critical issues.

"Alertness and performance decline gradually with partial sleep deprivation when sleep is limited to four or five hours each night."³⁶ Tasks take longer to accomplish; soldiers become inattentive; and comprehension and perception slow down. Sleep deprivation slows mental and physical skills in general and induces error. At least one study suggests that many studies conducted to assess the effects of SUSOPS on information processing may have underestimated the effects because the tasks used did not involve continuous cognitive processing.

"When soldiers perform a number of cognitive tasks continuously over a long period, larger performance deficits are likely to occur. . . serial reaction time and encoding/decoding decreased to 76% and 72% respectively from baseline levels after 24 hours. After 48 hours of continuous work, these values decreased to 43% and 41% respectively. Logical reasoning decreased to 57% of baseline levels after 24 hours and 26% after 48 hours."³⁷

Fear and stress tend to magnify the problems associated with fatigue on the real battlefield. The more fatigued one becomes the more stress and fear are a problem.

Providing for unit and vehicle security involves 24-hour local security (often patrolling), 360-degree security, LP/OP, and air guard. The organic assets the tank company commander currently has available to conduct security operations are marginally effective against infiltration and attack by dismounted infantry.³⁸ Fatigue and security are not suddenly an issue with the introduction of a 3-man tank. The problem, however, is more acute. Technology enhancements may improve the situation; however, it remains for soldiers to man the systems 24-hours a day for extended periods of time.

An often cited solution to crew fatigue problems is the idea of rotating crews on a regular basis. This is especially true of studies on reducing the crew to as few as two men. The German Army is considering a Blue Team/Gold Team concept (one crew on and one off) in their study to convert to two-man crew vehicles.³⁹ The French Army considered a similar concept in the original manning plan for the Leclerc.⁴⁰ They have since revised their proposed doctrine to have only one extra crew for each platoon of manned tanks. The extra crew may be used as either a complete crew replacement or for individual replacements.⁴¹

The implications of having two crews per vehicle are significant. First, the strategy does not realize any real manpower savings, a contributing motivation behind the effort to reduce crew sizes (hence the French Army position change). Second, the solution requires a second vehicle per tank (or at a minimum per platoon) to transport the relief crew(s). This represents an enormous logistical support cost. In addition to the fuel and parts required to maintain the transports, providing food, security, and other support for the relieved crews will require more repairmen, logistics personnel, and other soldiers. Third, the additional vehicles represent a larger battlefield signature and new vulnerability for armor units. An enemy could focus on destroying the more vulnerable relief crews rendering the isolated forward troops combat ineffective due to fatigue. Replacement crew options therefore may not be viable.

Degraded Crew Operations

The final area for consideration is degraded operations. Three crewmen can operate the four-man tank in a degraded mode. Historically, soldiers are wounded and become sick on the battlefield. As stated, the army doctrinally expects manpower shortages to occur (hence the existence of the loader task, reassign[ed] to replace casualties as necessary). The M1 tank is designed with enough redundancy to allow a crewman to fire the tank from the tank commander's position without a gunner. Crews train for the task and it is tested during tank gunnery exercises. Redundancy is not 100% and the task is more difficult from the tank commander's position than from the gunner's. Crew degradation seriously impacts other critical tasks and responsibilities, such as command and control, reporting, and navigation, as well. A three-man tank configuration must allow for two men to operate the tank with about the same efficiency as the degraded four-man crew. Current technology is insufficient to allow this for any extended period of time.

III. MANPRINT

The study next focuses on the army's efforts to integrate human dimension factors with its procurement programs. For many years the army's system for acquisition of materiel has been concerned with "a piece of equipment." Research suggests that no matter how well the piece of equipment works in development, the actual performance in the field is degraded because of the environment and the soldier/user. When the developmental phase of the acquisition does not consider the user, the equipment's true worth is rarely realized and the army must spend additional money to correct user-found deficiencies.

This chapter first examines the army's program for integrating human dimension considerations into the materiel procurement process, MANPRINT (Manpower

Personnel Integration). Second, it looks at the Soviet tank development program and their lack of effort to integrate human dimension issues into their systems. Next the chapter considers the AGS program to examine the integration of MANPRINT in an actual acquisition program. The chapter concludes by looking at two test facilities which hold great promise for testing and evaluating human dimension issues in emerging technologies.

MANPRINT

The MANPRINT program is a major military system procurement initiative adopted by the army to focus on the needs and capabilities of the soldier. The program is a comprehensive management and technical effort to ensure total system effectiveness by continuous integration into seven areas of user concern: human factors engineering, manpower, personnel, training, health hazards, system safety and soldier survivability throughout the development and acquisition cycle of army materiel.

Among the objectives of MANPRINT required by AR 606-2, Manpower and Personnel Integration (MANPRINT) in the Material Acquisition Process, the governing regulation, are the following:

- Increase the army's warfighting capability by enhancing the operational effectiveness of the total system
- Influence soldier-materiel system design for optimum total system performance by considering human performance and reliability issues related to the MANPRINT domains before finalizing the functional allocation of tasks among people, hardware, and software.
- Ensure that army materiel systems and concepts for their employment do not exceed the capabilities and limitations of the fully equipped soldier to operate, maintain, supply and transport the materiel in its operational environment consistent with tactical requirements and logistical capabilities.

In short, the MANPRINT program seeks to answer the question: "Can this soldier with this training perform these tasks to these standards under these conditions?"⁴²

One of the more significant policies required by the regulation is that MANPRINT be accorded equal priority with all other system characteristics, such as overall system cost, program scheduling and overall system performance to ensure effective man-materiel interface. The difficulty with meeting the requirement is that MANPRINT issues involve both quantitative and qualitative measurements.

The army does fairly well identifying and testing quantifiable measures. The Army Research Laboratory's (ARL) Human Research and Engineering Directorate (HRED)⁴³ maintains a database of soldier performance characteristics. From this database come target audience descriptors (TAD) indexed to performance capabilities and measurements such as the height and weight range of the 95th percentile of the male or female soldier and the most comfortable and least fatiguing angles for seating positions in vehicles. O'Keefe, Henriksen, and Barber's study, Human Performance Data Relevant to the Armored Family of Vehicles, points out, "Although a great deal is known about the types of performance which degrade during CONOPS, there is little empirical evidence on the methods of retarding the degradation." They note that the greatest deficiency is a lack of field testing.⁴⁴ This provides an important point of reference for evaluating the success of the integration of MANPRINT issues into acquisition programs such as the AGS.

The human engineering community has developed a large number of computer tools and techniques to model crew workload and evaluate human engineering factors. The 1990 book, MANPRINT: An Approach to Systems Integration lists 47 tools and techniques to evaluate manpower, personnel and training (MPT) issues and 88 advanced human factors engineering (HFE) tool technologies for use in systems design.⁴⁵ The techniques support weapons system development from concept exploration through production and deployment. Empirical data from computer models

provides a comparison method for competing systems. The large number of techniques and tools may be as much a part of the problem as they are a part of the solution to MANPRINT integration .

Entire studies are conducted just to determine which tool or technique is the best suited for a particular project. The 1990 study, A Survey of Human Factors Methodologies and Models for Improving the Maintainability of Design of Emerging Army Aviation Systems, reviewed methodologies and models to judge which potentially best improved maintainability and design of aviation systems. The study addressed important fiscal concerns associated with rising maintenance costs. In the end, it recommended more evaluation on two models to "determine their *appropriateness* [emphasis added] for improving the maintainability and design of emerging" aviation systems. The study also recommended five models for evaluation to determine " *if* it is both feasible and desirable to *modify* them [emphasis added]" to improve their utility.⁴⁶

Another study, HARDMAN III Utility Assessment Analysis, examined the utility of a MANPRINT analytical tool to assist in resolving MPT issues associated with equipment design. The authors did not recommend the army accept or sponsor the HARDMAN III model due in large part because the model itself was not user friendly to operate and it did not adhere to MANPRINT principles.⁴⁷

The army must conduct some studies to ensure the utility of emerging analytical tools. Many systems are still in early development. Additional methods will continue to emerge to aid in the assessment and integration of human engineering issues into systems development. One must question, however, the utility of a large set of models which themselves must be studied and compared just to determine their own utility to the process.

Many MANPRINT studies produce purely technical findings, such as the time it takes to set-up or tear down system. Others produce findings constrained by the design

of the test and evaluation itself.⁴⁸ Dr. Kathleen Quinkert of the U.S. Army Research Institute for Behavioral and Social Sciences (ARI) in 1990 noted,

"The simulation models, which are considered adequate for front-end analyses of the equipment, rarely make provisions for the consideration of the human element. In a similar light, field tests which include the human element have proven very costly and perhaps too untimely for their results to affect the ultimate design of the system."⁴⁹

The most cost effective way to influence equipment design is to integrate human factors engineering into the concept evaluation and design phases of the acquisition cycle. A 1985 US Government General Accounting Office report concluded that the concept evaluation phase of acquisition has the greatest effect on the system's life cycle costs.

"Many studies of life cycle and weapons systems supportability show that about 70% of a system's life cycle costs are determined by decisions made prior to Milestone 1. After the concept exploration phase, as development proceeds and the design becomes more set, changes to ensure that trained personnel can operated and maintain the system are more difficult and costly."⁵⁰

Money spent on developing and testing models and techniques might be better spent on early simulation tests based on human dimension design and soldier-machine interface (SMI) challenges identified early in the procurement process. Because these issues are identified early, as specified by the regulation, testing could be performed in parallel with the early phases of design.

Soviet Tank Design and the Human Dimension

The Soviet three-man tank program is often cited as proof that the three-man system can and does work. The inference is that their success bodes well for ours. The unfortunate truth is the preponderance of the information available indicates the Soviets barely, if at all, considered the crew in their tank designs.

The Soviets arguably produced one of the best tanks available before and during World War II, the 5-man-crew T-34. Subsequent improved Soviet tank models were evolved from this basic design. Their analysis that 90% of the hits made on a tank occurred above a meter from the ground resulted in a prime design imperative to lower the frontal profile of the tank.⁵¹ Soviet advances in making components lighter meant they could add more armor to improve protection. A smaller engine meant a reduction in the overall height of the tank. They shortened the vehicle by changing to a transverse engine placement.⁵² Each time developers improved a component (usually meaning smaller or lighter), they made the tank correspondingly smaller or lower. Improvements, such as two radio sets, a generator, and navigational equipment, were made in commander's tank models at the expense of the ammunition load of the tank.⁵³

A 1990 article by Lieutenant-General S. Maev, Deputy Commanding General of the Ground Forces for Armaments, provides alarming insights into their consideration of the soldier in their tank development programs. He describes observing a disappointing performance on a hot day by a tank regiment's best firing battalion. Their attack was not effective and their gunnery inaccurate. The angry regimental commander questioned the leaders regarding their performance. The answer came from the deputy battalion commander, "... it is so hot in there that inside the tanks it has become a virtual living hell." General Maev agrees, "One of the very greatest misfortunes that befall the crews of combat vehicles is the poor habitability of those vehicles, or rather the low amount of comfort that they have to work in when occupying their compartments."

Their combat vehicle designs have not adopted the full measure of requirements from the Medical Technical Department to improve habitability and address safety concerns. Noise levels exceed permissible levels by 10 to 40 dB; illumination in most vehicles is 20 - 50 lumens below required levels; the lack of climatic control and ventilation causes temperatures to exceed acceptable standards and propellant fumes

inside the turret to remain in high concentrations, some two to ten times the maximum permissible levels, for 15 - 20 minutes after firing. Their own studies indicate that at times, due to an unsatisfactory microclimate inside the vehicle, speeds drop by 79%, firing times increase 35%, and the number of misses increases by 40%. General Maev acknowledges they have developed filtration systems capable of quickly removing carbon dioxide from the air inside tanks under a wide range of temperatures, "But at the same time the decision to prepare [filtration systems] for series production and application [on tanks] . . . has not been reached."⁵⁴ The U.S. Army's record for the integration of human engineering factors into its weapon systems is fortunately better.

The AGS Program

The AGS program provides the opportunity to examine the integration of MANPRINT in the weapons systems acquisition process. Two documents are critical to the analysis, the System MANPRINT Management Plan (SMMP) and the Test Evaluation Master Plan (TEMP) along with the test design for the early user test and evaluation (EUTE). MANPRINT issues identified in the SMMP can be compared with the completeness with which the issues are tested in the TEMP. The importance of the connection is that the army makes procurement decisions based on the results of testing. The AGS is scheduled to undergo early user test and evaluation EUTE in January 1995. After the EUTE, the army will decide whether to proceed with the Low Rate Initial Production (LRIP), 26 AGS with an option to buy an additional 42. The EUTE represents the last opportunity to influence design changes prior to operational testing.

The SMMP provides an audit trail of previous phases of acquisition, identifies current and anticipated issues, and lists task assignments to resolve the issues.⁵⁵ The SMMP articulates and refines each MANPRINT issue through a series of questions which serve to highlight details and remove ambiguities concerning the nature of the problem. The TEMP describes the overall plan for conducting various tests of a system,

identifies minimum critical performance criteria, and details the objective, scope, limitations and constraints of each phase of testing. A companion document to the TEMP describes exact methods and criteria to evaluate each issue. (See Appendix 2) The goal is to test and evaluate a system's operational effectiveness and sustainability under near operational conditions.

SMMP

The AGS SMMP clearly and concisely identified the specific parameters for each MANPRINT domain and six MANPRINT issues in the AGS program. Each issue was rated as being in a green or amber status. Two of the six issues dealt with training and health hazards, and are not discussed here.⁵⁶ The other four issues dealt directly with the human dimension issues identified in the previous chapter:

- Ability of soldiers from the target audience to operate, maintain, repair, and support the system to prescribed performance standards in all uniforms and under all environmental conditions.

- Impacts of crew reduction (mission performance during sustained operations and degraded mode operations).

- Identification of structure, manpower requirements, personnel requirements and impacts of a 3-man crew on the armored vehicle crewman career management field (CMF 19) grade structure.

- Effectiveness of the system after loss of subsystem components or personnel.⁵⁷

One constraint of note was to place further emphasis "on human needs and task performance after personnel and/or equipment losses during extended missions."^{58,59} Appropriately, the issues focused on what might be considered the bottom line MANPRINT question associated with the AGS, "Can a properly trained soldier perform his duties as part of a three-man armored vehicle in a continuous land combat environment for an extended period of time?" Asking the correct question, however, is not enough. The question once asked must be acted upon. This did not occur completely

with the AGS. There were 39 specific questions associated with the four issues noted above, of these, 41 percent (16) were not answered prior to the EUTE.⁶⁰ Thirteen of these, one third of the total questions raised, if training and health and safety issues are not considered, dealt with the impact of crew reduction.⁶¹ (The 13 questions are listed in APPENDIX 3)

MANPRINT Issues and Supporting Questions

MANPRINT Issue	Clarifying Questions	Questions Answered	Percent Not Answered
Ability of soldiers to operate, maintain, and support system	22	18	18%
Impact of crew reduction	7	2	71%
Training Impacts	12	1	92%
ID Safety and Health Hazards	17 *	15	12%
Force Structure Impacts	8	2	75%
Degraded System Effectiveness	<u>2</u>	<u>0</u>	<u>100%</u>
Total	68	38	44%

*Does not include four questions also listed under first issue

A stated goal in the SMMP was to ensure evaluation of MANPRINT issues during EUTE if feasible.⁶² This objective delayed addressing the issues until too late in the process to reasonably affect design. However, from this one might deduce that the EUTE test design would address the resolution of these issues to the greatest extent possible. The examination of the TEMP shows this was not the case.

Integration of the issues raised in the SMMP with the EUTE issues did not occur. The SMMP issues were largely ignored. There are two reasons for this failure. First, one arm of Combat Development branch developed the SMMP, another develops critical operational issues/criteria (COIC) for operational testing.⁶³ The former agency, PM-AGS (Program Manager) is located in Warren, Michigan, the latter, TSM-AGS (TRADOC

Systems Manager) in Fort Knox, Kentucky. Second, the green and amber ratings for the SMMP issues reflected no problems need be raised.

The issue of ratings is a significant shortcoming in the MANPRINT system. In short, there is neither a codified criteria or rating scheme to evaluate MANPRINT issues, nor a requirement for either the project manager or the Deputy Chief of Staff for Personnel (DCSPER) to rate the issues.⁶⁴ This means any evaluation that is conducted is subjective in nature and lends itself to being wavered or simply overlooked. PM AGS took a significant step by using a modified integrated logistic support management team (ILSMT) methodology to rate the status of the AGS human dimension issues;⁶⁵ however, the green and amber ratings were not substantiated with tangible findings for resolution of the unanswered issue questions.

TEMP

The AGS TEMP identified six issues for the EUTE (See Appendix 2). The first issue dealt primarily with rigging the AGS for deployment by air. The second was a comparison between the capabilities of the AGS with those of the M551A1 Sheridan. Four of 13 measures of evaluation (MOE) for that issue addressed SMI, however, only measure of performance 2-2-6-2, dealt directly with automation and system fightability and usability.⁶⁶ That MOE was to be measured only through MANPRINT questionnaires not during force on force operations, but during gunnery.⁶⁷ The third dealt almost exclusively with the operational readiness and logistic supportability of the AGS and only indirectly with human dimension issues. The fifth issue addressed communications; however, of thirteen measures of performance for that issue, only three were evaluated.⁶⁸

Only the fourth and sixth issues involved human dimension issues. While the fourth addressed soldier machine interface, software, and the human factors engineering (HFE) design, issues such as leader vehicles, degraded vehicle and crews, security, and sleep plans were not addressed. Additionally, test limitations did not allow

for testing of more than one third of the measures of performance. The sixth issue dealt with the differences in performance while in MOPP.⁶⁹ Nothing in the test was specifically designed to evaluate the impact of reduced crew size.⁷⁰

The comparison of the AGS SMMP and TEMP reveal a lack of integration between the two documents. Primarily the EUTE became a comparison between the AGS and the Sheridan, the vehicle it will replace. That is an important comparison; however, the test falls short in achieving the goal outlined in the SMMP: to ensure evaluation of MANPRINT issues during EUTE.⁷¹ The ramifications are significant. Issues designated to for testing in EUTE must now be addressed during operational testing. This means at least 26 AGS systems are being built without adequate testing to discover if the system exceeds the capabilities and limitations of the fully equipped soldier to operate, maintain, and supply the vehicle in an operational environment. As with many procurement programs, the answers which reveal conflict between human dimension factors and the AGS design may come too late in the process. The army may not resolve issues which arise without greatly affecting a program's cost and schedule. The result may be a program which does not achieve adequate consideration of human dimension issues, this with a system which may have enjoyed one of the army's best MANPRINT efforts.

MWTB and the U-COFT

Despite this less than optimistic evaluation of the AGS/MANPRINT program there are more positive efforts being made in the MANPRINT arena. Field testing with simulators provides the ability to conduct soldier-in-the-loop front-end analysis. Two armor training simulators can be modified to provide the opportunity for soldier-in-the-loop front-end analysis and early testing of new tank components. The first is the Unit-Conduct of Fire Trainer (U-COFT);⁷² the second is the SIMNET-D⁷³ or the Mounted Warfare Test Bed (MWTB). These systems provide accurate, automated data collection via

embedded data sampling in addition to data collected through researcher observations and crew interrogation.

The use of trained soldiers, familiar with the basic equipment, provides both quantitative data and qualitative feedback on actual or prototype systems. Soldiers are able to evaluate the integration of the human element into the design and provide recommendations for design improvements which may be only inferred in tests using computer modeling. Soldiers can also provide insights into the doctrinal employment of the system, something a model cannot.

Dr. Quinkert used soldier-in-the-loop tests in the U-COFT to explore the effectiveness and possible soldier-machine interface (SMI) problems with the new M1A2 tank commander's independent thermal viewer (CITV).⁷⁴ Her study, using soldiers vice computer simulations, provided combat and training developers the opportunity to identify design flaws, identify of potential training problems, and examine the operational effectiveness of the CITV. The results of this research led to subsequent testing on the design of a new commander's control handle to operate the tanks firing system, research on an alternative icon to display the relationship of the turret to the hull of the tank, and "research on tactics, techniques and procedures at platoon level."⁷⁵

ARI sponsored an iterative set of company and battalion level tests on a future command, control and communications (C³) system, the Combat Vehicle Command and Control (CVC²), using MWTB. The company level test integrated three systems, each independently tested and refined using the MWTB and the U-COFT.⁷⁶ Researchers studied the effects of integrating automated C³ systems by combining three systems onto one vehicle.⁷⁷ The study resulted in a number of design modification recommendations for the CVC², important observations regarding soldier-machine interface problems, observations on crew workload distribution, and implications for future testing methods.⁷⁸

These efforts represent positive strides in early equipment testing and provide tangible proof of the power of prototype testing early in the design phase. This is the type of programs which need greater funding and increased emphasis. The MWTB is not an inexpensive system; however, because it is programmable and reconfigurable to represent system designs, it is an efficient way to prototype equipment before the actual prototype can be built. Through the use of such systems, SMI challenges, especially with regards to software designs can be addressed.

IV. FUTURE TECHNOLOGY

This chapter addresses emerging technologies likely to be incorporated into the future main battle tank. Technology advancements are divided among the areas of responsibility identified in Chapter 2 and are discussed from two perspectives. First, the technology is identified and defined, if necessary; second, associated human dimension problems are considered. Improvements are not limited to the loader's area of responsibility as advancements must also be made for the other crew positions to compensate for the increased workload from the loss of a crewman. The over-arching technical challenges for improving the tank are first to make it more lethal, better protected, more survivable, and more sustainable⁷⁹ without making it any larger or heavier than the current configuration; and second, to make the tank smaller and lighter if possible.

The U.S. Army Tank-Automotive Research Development and Engineering Center (TARDEC) program, Crewman's Associate Advanced Technology Demonstration (CAATD), seeks to demonstrate crew station "enhancements possible through the application of advanced technologies."⁸⁰ Through this program the army hopes to automate crew tasks to allow a reduction in crew workload and ultimately crew size. The program's focus is on advanced human interface technologies, such as helmet mounted displays,

panoramic displays, and voice interfaces, that will enable the design of a revolutionary soldier machine interface (SMI).⁸¹ Many of the advancements identified in this chapter are the result of CAATD.

Operational Tasks

The primary advancement is the autoloader. There is a technical reason for using an autoloader aside from the desire to replace the loader. The United States uses solid propellant gun systems. Rounds must be small enough for a soldier to load and maneuver inside the turret; therefore lethality and range of the current system are constrained by the size of the projectile. If the 120 mm gun continues as the primary weapon, then achieving greater round velocity and thus greater range and armor piercing capability requires more propellant and a longer penetrator. This necessitates using a two-piece projectile and, therefore, an autoloader.⁸²

The AGS autoloader specifications required:

- A continuous firing rate of twelve rounds per minute.
- Ejection of misfires and spent casings from the vehicle without a crewman moving from his station.
- Selection, loading, stowage, and re-selection of ready rounds of ammunition.
- Unloading and re-stowing an unfired round.
- A read-out of main gun ammunition quantities, by type, and status of autoloader function readable at both the commander and loader positions.
- A built-in-test capability.
- Manual loading of not less than three rounds per minute.⁸³

Assuming the autoloader design perfected during the AGS program, the only significant problem remaining is the time and difficulty of manually loading the main gun. The standard to manually load three rounds per minute was not met and that rate requirement was under review at the end of 1994. If the army maintains the current gunnery standards for firing the 120 mm gun, the gun would have to be reloaded and a

target acquired and killed in less than 38 seconds.^{84,85} The average manual loading time for the AGS was one minute. This is both a technical and human dimension shortcoming in the design.

Main Weapon Firing and Engagement Tasks

Improvements in these two areas primarily affect the gunner and tank commander. The most significant advancement is a target acquisition system. CAATD envisions a system which will detect, recognize and identify targets. Detection is the perception of objects of military significance, such as a man or helicopter; recognition is a distinction between those objects; and identification is further discrimination between types of objects, such as an M1 tank and a T72 tank. The target acquisition system sensors would automatically detect threat activity, cue targets, and present the crew with a Fire or No-Fire decision.⁸⁶

This process is not overly complicated. Computers do much of the work; however, it is doubtful, given the proximity of other vehicles and soldiers, if automation will completely replace the crew making the decision to fire. Reacting to threat alerts is more complicated than merely monitoring a firing system. Tired, stressed armor crewmen, engaged in direct fire combat, maneuvering and controlling their own vehicles and those in their units, will have to make the decisions.

An externally mounted gun introduces new SMI problems. The gunner and tank commander need remote optics to see, presenting designers the challenge of replicating the freedom of movement and fields of view the tank commander currently enjoys. Helmet-mounted displays will likely provide a solution. A number of factors, including how well designers develop the SMI, product reliability, and the ability of external cameras and associated hardware to withstand the combat environment, will greatly impact the crew's ability to use exclusively remote systems

Maintenance Tasks

CAATD includes automated logistics and embedded vehicle self-diagnostics. Automated logistics involves the vehicle self-monitoring such items as fuel and oil levels and ammunition on hand. Once preset minimums are met, the system would notify the crew and supply of the need to rearm or refuel, relieving the crew of manual reporting requirements. Self-diagnostics will be an improvement over the current system of fault warning lights and include troubleshooting and "quick" fixes for emergency situations.⁸⁷

The increased use of sensitive components places new demands on the crew to maintain that equipment. Equipping vehicles with self-diagnostics is a positive trend, although it will likely not eliminate vehicle PMCS. This, coupled with automated reporting, may shorten the time spent troubleshooting equipment failures and maintenance down time.

A caveat is that the increased use of sensors and other high dollar, third wave technologies increases requirements on logistics and the number of high dollar components on the tank. The army's record for maintaining readily available expensive repair parts does not support this requirement. Armor battalions currently do not maintain many spare high dollar components on hand in their prescribed load list (PLL).⁸⁸ Little advantage is gained if the crew can diagnose the problem but the logistical system cannot supply the repair parts.

There are also interface problems to solve: first, between automated and non-automated systems; second, between combat and combat support elements; and third, in vehicles whose automation fails. The army incrementally upgrades technology in units. The last active duty unit to replace their M60A3 tanks did so over ten years after the initial fielding of the M1 tank. Meanwhile, the M1 had been upgraded twice and the third version, the M1A2, was about to be fielded. During DESERT STORM, two brigades in the 1st Infantry Division had M1A1 tanks. The other brigade was M1IP (improved

product) tank equipped.⁸⁹ Additionally, the 1st Infantry Division did not have Mobile Subscriber Equipment (MSE) and other divisions did. Were equipment mis-matches to occur in the future between automated and non-automated units, especially at battalion and below, there could be significant interface problems. Manual systems would have to be implemented without the manpower available to accomplish those tasks. In such a situation, automation could serve to significantly slow the pace of operations in the unit equipped with reduced-crew vehicles.

Automated combat systems achieve no manpower savings if the tail is not also automated. The army must first commit significant resources toward building a combat support information network. It must dedicate more frequencies to logistics in at a time when increased command and control automation is already competing for limited numbers of frequencies. An increase in transmission of logistics data over the radio means a larger electronic signature on the battlefield.

Like combat systems, the army incrementally upgrades combat support systems, but often at a much slower rate. In an M1A2-equipped company, the first sergeant and maintenance vehicles do not have IVIS. None of the support elements, more than two-thirds of the vehicles in an armor battalion, are IVIS equipped. Logistics operators have no automated interface with combat vehicles. Additionally, combat support elements are the worst equipped in terms of communication equipment.⁹⁰

An automation SMI problem too often overlooked is what to do if the automation fails. This applies across the spectrum of automation, not just with logistics. Systems may perform well when everything works, but rarely are there procedures included to enable operations to continue if one or more parts malfunction. Designers must address this aspect of SMI. Automation permits personnel reductions to occur. In an optimized system, there are insufficient additional people available to perform tasks manually. This problem can not be solved simply by establishing standard operating

procedures. User-friendly error handling, soft system crashes,⁹¹ redundancy, and malfunction procedures and work-arounds must be designed into the equipment.

Tactical Tasks

Advancements in this area primarily affect the driver and tank commander and are linked to a system under development, the Combat Vehicle Command and Control (CVC²) system. The system incorporates the position navigation (POSNAV) system which provides vehicle location and facilitates maneuver, a digital command and control display (CCD) (IVIS-based), and the commander's independent thermal viewer (CITV).

Simulator test results suggest the driver can assume the majority of the driving and enroute navigation duties using POSNAV and the CAATD enhancements computer assisted driving, route planning, and obstacle avoidance.⁹² He would receive movement and route instructions from the commander and then execute moves with minimum interaction with the commander. The greatest advantages would be achieved during extended administrative or low threat movements and by releasing the vehicle commander from constant navigation responsibilities. However, aided driving has limited combat utility. The system would likely free the driver to perform other tasks for only short periods of time. As such, the applications are less dramatic for the tank than for vehicles operating in rear areas with a transportation infrastructure. Planned crew reductions based on automated driving are dubious because of these limitations during combat use.

CVC² enhancements for the tank commander will integrate an IVIS-based distributed information network with CITV. The latter system will allow the commander to scan the battlefield, acquire targets and cue the gunner independently. CITV will interface with the CCD and, through a horizontal information distribution network, vastly improve situational awareness throughout the battlefield.

CVC² will have a digital map display to provide near-real time locations of friendly units, improved navigation capabilities, and digital overlay functions. The commander

will be able to receive, compose, and rapidly disseminate operations orders on the CCD. CVC² will also automate reporting and calls for indirect fire.⁹³ While this system may ultimately provide army ground combat forces the ability to make rapid and timely decisions and a decided advantage over threat forces, research suggests that the most significant SMI problem to overcome is one of information overload. Digitization may increase workloads in some areas of crew duties.⁹⁴

Communication (C²)

Crew size reduction relies heavily on automation, which in-turn often requires a greater use of radios. Aside from SMI problems, radios and radio frequencies may be the greatest challenges to the increased use of automation. Vietnam-era radio's are still in use throughout the majority of the army, despite the existence of the single channel ground airborne radio system (SINGARS) for over ten years. That system has never been fielded throughout the army and, in order to best exploit a distributed information network, an even newer radio technology must be adopted.⁹⁵ Frequency management is a growing problem. There are a finite number of frequencies on which systems can operate and a finite amount of data which can be sent on a frequency.

Security

The army is developing the Vehicle Integrated Defense System (VIDS) consisting of three parts: threat warning systems, signal processing and decision making algorithms, and countermeasures. VIDS is an adaptation of concepts and approaches used in aircraft defense systems and is seen as a possible alternative to additional armor.⁹⁶ There is also an advanced technology demonstration for hit avoidance to develop a system to counter enemy munitions.⁹⁷

The adaptation of aircraft systems to the tank is not coincidental. Many technologists draw a correlation between the cockpit of a high performance combat aircraft and the ultimate design of the crew compartment in armored vehicles. To

make the two systems more alike involves the increased use of automation and sensor arrays, and greater SMI challenges.

The human dimension challenges of operating in a continuous combat environment, degraded operations, security, leader vehicles, and workload distribution are affected by the extent to which the vehicle is automated and the SMI. Equipment must be designed for intuitive use. That is, soldiers are comfortable with the design, understand its use, and can easily and quickly grasp how to use the equipment. If a system is user-friendly in this way, the user spends little time trying to understand how to use the equipment. He can then spend the majority of his time trying to understand how exploit the technology and often finding new and novel uses for the equipment. If these problems are addressed and ultimately solved early in the design process, then a more usable system is developed.

The problem with sensors --even assuming vast improvements are made in SMI-- may ultimately lie with sensor technology and vulnerability. "Masking or modifying or faking the signature of a thing may well be easier than making the thing itself, and is certainly cheaper; hence it is questionable whether the sensors can ever be made sophisticated enough."⁹⁸ Enemies might focus on defeating the sensors, instead of a vehicle's armor. Van Creveld argues that sensors and computers may not be good enough for the complex land combat environment without marked improvements. He observes they are "for the most part good enough only for the simple environments presented by air and sea; they are not sufficiently sophisticated to make out men from their background and friends from foes."⁹⁹ As an example, the use of an automated anti-fratricide system should decrease the cognitive workload on the crew. However, if the system is not sophisticated enough to recognize friend or foe and only identifies a vehicle as "friend" or "unknown," there is not enough information to make a decision to fire. In ground combat, there are almost always friendly forces operating to the flanks, front, and rear. Even combining the identification system with improved

situational awareness and friendly vehicle locations through IVIS may not ensure fratricide will not occur.

The army is committed to the increased use of automation and digitization in the new Force XXI concept. The Chief of Staff of the Army presents the challenge "not to limit our future commanders by shallow thinking about emerging technology."¹⁰⁰ Unfortunately many view interjecting reality, especially in the form of human dimension issues, as limiting the potential of those technologies. To the contrary, a holistic approach to technology, incorporating both the soldier and the machine, can serve to ultimately increase the potential of the technology. Consideration of human dimension issues early in the concept and design phase does not limit technology. Seen from the perspective of intuitive use, human dimension issues are enhancements to technology. The greatest dividend will be paid if the designer and innovator address the problems as early as possible.

V. CONCLUSION AND RECOMMENDATIONS

The use of sophisticated technology places new demands on the crew to operate the specialized equipment. At the same time, some technologies will change the way the crew functions. The dilemma is that technology innovators are inventors. It falls to the combat developers to integrate the inventions into the overall vehicle design. The soldier, who had little or no input into the vehicle design, is the operator. Human error too often is ultimately blamed when the system does not operate at peak capability or when errors occur. This is even if the error is attributable to poor SMI design.¹⁰¹ Inventors and technology developers succeed best by thinking "outside the box," in the realm of the possible, unconstrained by fiscal or physical limitations. Users operate in a harsh, complicated environment with equipment produced by the lowest bidder.

As noted earlier, the elimination of a crewman (or men) requires the implementation of technology solutions for tasks which other crew members cannot perform. The preceding section introduced SMI and other human dimension considerations involved in the introduction of new armor technologies. MANPRINT seeks to solve human dimension problems early in the design process. Yet there exists no standard or common principle to guide this integration.

One ARI-sponsored study pointed out that no single definition of a "good" system exists. That study defined a good system as one which is **usable and useful**. A usable system enables users to do the things they need or want to do and is well liked. A useful system is one which can be operated successfully without undue effort or error.¹⁰² The good system standard is an evaluation of a system after it is built.

Simpkin identified fightability as a mysterious quality which conflicts diametrically with every other major parameter primarily because it is so difficult to quantify. He identified six elements in the concept of fightability: buttoned-up vision, ease of operation, clean functional design, habitability, crew contact, and escape and rescue. The operation and design elements related both to ergonomic design and the idea of intuitive use of a piece of equipment, that is, the user, without expending much mental energy or receiving much explanation, understands the function as self-evident. The habitability element was the recognition that crews in training and combat have to live in their tanks for days at a time.¹⁰³

Rarely do technology descriptions include any mention of the combat environment in which a vehicle will operate or how long an operation lasts. This directly relates to the duration of CONOPS, SUSOPS, and around-the-clock operations. A description of the operation is important to determining how long the crew must physically operate the vehicle in combat, for identifying the conditions under which they must sustain and maintain the vehicle, and to provide an idea of what other factors the crew and

especially the leader must consider while operating the equipment. The description can also serve to identify the terrain on which equipment can or can not be operated.

There is no doctrinal fightability standard for new technology. Such a standard would serve to force the consideration of new technologies within the context of the environment in which they must be operated. **Fightability** should be a description of the utility of a piece of equipment composed of: usability, ergonomic design, intuitive use, the operation's duration and a description of the combat environment, and the integration with other technologies. Using this description one can posit a series of questions to augment the prime MANPRINT question:

1. Can this soldier with this training perform these tasks to these standards under these conditions? (prime MANPRINT question)
2. Does the system accomplish what the user needs and wants it to do and is it well liked?
3. Can the system be operated successfully without undue effort or error and does it have a clean functional use?
4. When errors or malfunctions occur, does the system design handle errors in a user-friendly manner and incorporate redundancy, work-arounds, and considerations for manual interfaces?
5. Is the use of the equipment largely intuitive and operable without multiple inputs and layers?
6. How long, in terms of CONOPS, SUSOPS and around-the-clock operations, is an operation involving the equipment expected to last?
7. What is the intensity of operations and on what type of terrain can the equipment be operated (or not operated)?
8. What other operations will the crewman be performing at the same time he is operating this equipment?

Answering these questions may lead to greater compatibility between the soldier and his equipment. The evidence suggests that the army does not completely consider the user until early user and operational tests are conducted. By that point the equipment design is largely set and major redesign to accommodate the soldier cannot be accomplished except at great cost. The user is left to adapt and work through the SMI and other human dimension problems.

We must allow the technology designer to dream. But early in the design cycle we must also identify and actively pursue answers to the human dimension problems. To wait to resolve human dimension issues is to *de facto* ignore them. There is no one in the system at the project manager level with enough leverage to force combat developers to integrate the human dimension into designs. This is not to imply there is a need to add another bureaucratic layer on the procurement cycle just to enforce integration. There is, however, a need for more objective criteria for evaluating the status of human dimension issues. Otherwise, program managers, largely through the use of subjective criteria, can waive or ignore the integration of the human dimension.

The most glaring deficiency is the need for developers to re-ground themselves in the tactical environment of combat. It is highly unlikely that ground combat systems can ever be operated like a high performance aircraft. Ground combat units operate, fight, secure, and maintain their vehicles in hostile environments and in close proximity to the enemy. Combat system developers must be better at projecting the uses for the equipment they develop into that complicated environment.

If developers are diligent in their consideration of the human dimension, the problems are not unsolvable. The following steps would go a long way toward providing the user a vote in the development of the systems he must use. First, develop a fightability description for each new technology. Second, spend resources early to investigate and resolve human dimension issues in the initial designs. Third, codify a scheme for rating the status of MANPRINT issues. Fourth, conduct soldier-in-the-loop

testing early in the design phase, in addition to user juries, using simulations and mock-ups.

Finally, realistic testing equipment under extended operating conditions must take place. It is not enough to test the vehicle in 24 to 48-hour scenario. Soldiers can remain awake that long and still function effectively. Evaluators must routinely introduce stress, fatigue and degraded operations into tests. Only then can we identify, examine, and ultimately solve the problems associated with extended operations.

APPENDIX A

Loader Task List

From Main Battle Tank Crew Task Analysis - September 1987

Operational Tasks

- Reset circuit breakers in turret networks box
- Operate NBC system/turret blower motor
- Operate emergency engine shutoff
- Ground guide vehicle
- Assist refueling tank
- Operate elevation uncouple
- Assist in boresight operations
- Prepare loader's station for operation
 - Open/Lock loader's hatch
 - Erect crosswind sensor
 - Install antennas
 - Prepare ammunition door knee switch
 - Clear ammunition door tracks
 - Place main gun Safe/Arm handle in the Safe position
 - Verify that all other crewmembers have entered their stations
 - Unlock turret traverse lock
 - Place loader's guards in desired position
 - Report ready for power operation to tank commander
 - Wait for commander to turn on turret power
 - Turn on/adjust dome light
 - Ensure main gun status safe light is lit
 - Turret blower switch off
 - Ensure gun turret drive switch manual light lit
 - Turn on amplifier, AM 1780/VRC
 - Main power switch on normal mode
 - Power circuit breaker switch on
 - INT ACCENT switch on
 - Set RADIO TRANS switch to desired location
 - Put on and connect CVC helmet
 - Set intercom select to INT ONLY
 - Adjust seat
 - Adjust hatch
 - Install night vision viewer if required
 - Ready Report to Tank Commander
- Power down and secure loader's station
 - Stow loader's guards
 - Remove night vision viewer (if installed)
 - Wait until main gun has been traversed to rear
 - Lock turret traverse lock
 - Verify main gun is clear
 - Verify main gun has been safed
 - Close breach
 - Ensure gun turret drive is in manual mode
 - Verify turret blower is off
 - Ensure main gun status SAFE light is lit

- Close semi-ready ammunition door
- Close ammunition door
- Close hull ammunition door
- Stow coaxial ammunition belt
- Turn off amplifier switch
- Remove and disconnect CVC helmet
- Turn off dome-light
- Remove and stow antennas
- Close and lock loader's hatch

Main Weapon Firing Tasks

Loader's pre-fire operations

- Ensure main gun is out of travel lock
- Ensure turret lock is unlocked
- Have gun traversed over front fender
- Lock turret lock
- Remove main gun muzzle plug from end of tube
- Unlock turret lock
- Ensure gun turret drive is powered up
- Check replenisher fluid level
 - Add/delete FRH as required
- Open breech
- Return breech operating handle to upright position
- Perform a function check on the breech
- Assist in performing a firing circuit test
- Clear main gun
- Emplace loader's guards
- Place stub base catcher in position for firing
- Ensure commander's foot guard is in place for firing

Loader's firing operations

- Receive the fire command
- Open Ammo compartment door
- Identify ammunition
- Retrieve desired round from ammo rack
- Close ammo compartment door
- Ensure tube is clear
- Load main gun
- Arm main gun
- Ensure main gun status ARMED light is lit
- Ensure turret blower switch is ON
- Announce UP over intercom
- Brace and ready another round for loading

Loader's Misfire Procedures

- Receive the Misfire announcement
- Ensure main gun is armed
- Ensure main gun status ARMED light is lit
- On order, open breech
- Examine primer for firing pin indentation
 - If not indented, examine firing pin
 - If indented do next procedure
- Rotated round 180 degrees
- Spit on primer
- Reload round
- Arm main gun

- Ensure main gun status ARMED light is lit
- Ensure turret blower switch is ON
- Announce UP over intercom
- Brace for recoil
- On order, extract round
- Dispose of in accordance with unit standard operating procedures
- Loader's post firing operations
 - Place SAFE/ARMED handle in safe position
 - Ensure main gun status SAFE light is lit
 - Clear main gun
 - Turn off turret blower
 - Stow ammunition door knee switch
 - Stow loader's guards and stub base catcher
 - Ensure commander's foot guard is stowed
 - Remove spent stub casings
 - Close turret bustle ammunition doors
 - Close hull ammunition door
 - Dispose of spent casings

Secondary Armament Tasks

- Assemble loader's Weapon
- Disassemble loader's weapon
- Perform a function check on loader's weapon
- Mount and maintain loader's weapon
- Operate 7.62 mm loader's weapon
- Correct stoppages on loader's weapon
- Change barrels on loader's weapon
- Dispose of spent links and casings
- Load, clear, and maintain grenade launchers
- Engage targets with 7.62 mm weapon

Ammunition Handling Tasks

- Know and load ammo stowage plan
- Inspect and maintain ammo stowage compartments
- Stow, inspect, and maintain all ammunition
- Assist in ammunition breakdown
- Recognize ammunition and uses

Maintenance Tasks

- Inspect turret hydraulics
- Inspect hydraulic system reservoir
- Help inspect and maintain track and suspension system
- Check fire bottle pressure gages
- Clean engine and transmission fluid levels
- Inspect tools and basic issue items (BII)
- Inspect and maintain ammo stowage compartments
- Inspect and maintain loader's station
- Assist other crewmen as required

Tactical Tasks

- Cuts and mounts camouflage
- Probes minefields
- Assists in NBC operations
 - Takes radiac readings

- Uses M-8 alarm paper
- Conducts local decontamination
- Administers NBC antidotes as required
- Assists in consolidation and reorganization (wounded, ammo, fuel)
- Reassign[ed] to replace casualties as necessary
- Deliberate occupation recon and security team leader
- Emplaces/retrieves concertina wire
- Assists in construction of fighting positions
 - Clears fields of fire
 - Assists in emplacement/retrieval of minefields
 - Improves fighting positions
- Assists in quartering party activities
 - Recon for OPFOR
 - NBC recon
 - Locates and marks obstacles and booby traps
 - Marks entrances, exits, and internal routes
 - Locate and mark vehicle position
- Assists in vehicle recovery operations
- Assists in processing of enemy prisoners of war (EPWs)
- Assists in vehicle abandonment procedures
- Conducts local dismounted reconnaissance: fords, obstacles, etc.
- Distributes range cards
- Assists in demolition operations

Observation Tasks

- Observe target area of responsibility (approximately 180 degrees left side)
- Acquire, identify, and prioritize targets
- Use night vision equipment for target acquisition (PVS-2,5 etc.)
- Identify U.S. and foreign equipment

Communication Tasks

- Radio watch and monitor additional net on command tanks
- Places hot loop in/out
- Operate and perform operator maintenance on receiver and receiver-transmitter, t/sec wiring harness, and amplifier 1780
- Communicate using visual signals

Security Tasks

- Emplace and retrieve mines
- Sagger guard
- Air guard
- LP/OP
- Local security
- Assists in providing 360 degree security during tactical operations

Additional Duties

- Assists in land navigation
- Assist vehicle commander as necessary
- Provide driver relief as necessary
- Runner/messenger
- Assists in messing activities

APPENDIX B

AGS Issues from the Test and Evaluation Master Plan (TEMP)

*Denotes measures of performance not evaluated due to testing limitations

Issue 1. Is the AGS equipped unit deployable by tactical transport

Measure of Evaluation (MOE) 1-1-1 Ability of the AGS to be rigged for Low-Velocity Air Droppable (LVAD) delivery IAW procedures...

- 1-1-1-1 Time required and number of soldiers involved.
- 1-1-1-2 Changes to Natick rigging procedures, AGS configuration, modifications or reduction in requirements for rigging required
- 1-1-1-3 Determination of requirement for flight made by USAF pers.
- 1-1-1-4 Ability of LVAD rigged AGS to meet LVAD deployment physical requirements.
- 1-1-1-5 List of additional tools, equipment, internal air transportability kits or shoring required but not authorized for LVAD rigging.
- 1-1-1-6 Damage and level of severity that occurs to the AGS or USAF transport during loading or transport.

MOE 1-1-2 Ability of the AGS to be rigged for RO/RO delivery IAW procedures...

- 1-1-2-1...6 same as above but for RO/RO.

MOE 1-1-3 Ability of the AGS to meet USAF standards for LVAD deployment.

- 1-1-3-1 Completion of one successful airdrop.
- 1-1-3-2 Damage and level of severity that occurs during extraction to either the AGS or USAF aircraft.

MOE 1-2-1 Difference in time required between the AGS and M551A1 to be made fully mission capable by the crew following LVAD.

- 1-2-1-1 Time to derig AGS and M551A1 and restore all mission essential functions (MEFs).
- 1-2-1-2 Cruising range after LVAD for AGS and M551A1
- 1-2-1-3 Amount of ammunition available after LVAD for AGS and M551A1
- 1-2-1-4 Ability of primary, auxiliary, and thermal sights to retain boresight after LVAD for AGS and M551A1.

MOE 1-2-2 The AGS must be made fully operational by the crew following RO/RO delivery in less time than the M551A1.

- 1-2-2-1 Average time required to roll off and restore AGS affected MEFs.

MOE 1-3-1 Certification of the AGS at level 2 protection by USAF for RO/RO transport.

- 1-3-1-1 USAF ASD approval of loading procedures.
- 1-3-1-2 Aircrew approval of Army loading procedures.
- 1-3-1-3 Number and type of variations from IAT procedures required.
- 1-3-1-4 Number and type of waivers or special procedures required.

MOE 1-3-2 Time required for AGS RO/RO at level 2 protection.

- 1-3-2-1 Time required to modify AGS with level 2 protection to meet RO/RO requirement.
- 1-3-2-2 Time required to roll on/roll off AGS with level 2 protection.
- 1-3-2-3 Changes to AGS configuration or Natick rigging procedures required to accommodate unit load configuration.

Issue 2. Can the AGS equipped unit defeat the threat?

MOE 2-1-1 Difference in the AGS unit's mission success compared to that of the M551A1 in support of infantry offensive operations.

- * 2-1-1-1 Personnel casualty rate for red and blue dismounted infantry.
- * 2-1-1-2 Casualty rate (kills) for red and blue direct fire weapons.
- 2-1-1-3 Percent of forces surviving red and blue direct fire weapons.
- * 2-1-1-4 Percent of missions where enemy unit or positions not identified before enemy fires on BLUEFOR.
- * 2-1-1-5 Percent of blue casualties caused by AGS and M551A1 fires.
- 2-1-1-6 Percent of missions where blue direct fire casualties are greater than 40 percent.
- 2-1-1-7 Median time to meet mission objectives (time to complete moves, to take obj.).
- * 2-1-1-8 Percent of moves not completed within the established TF order specifications.
- * 2-1-1-9 Rate of advance.
- 2-1-1-10 SME observations on utilization of AGS and M551A1 in support of offensive operations.

MOE 2-1-2 Difference in the AGS unit's mission success compared to that of the M551A1 in support of infantry defensive operations.

- * 2-1-2-1...3 same as for MOE 2-1-1
- * 2-1-2-4 Percent of blue casualties caused by AGS and M551A1 fires.
- 2-1-2-5 Percent of missions where blue direct fire casualties are greater than 40 percent.
- 2-1-2-6 Percent of missions where blue unit fails to deny enemy penetration of specified boundaries or areas.
- 2-1-2-7 Median time to meet mission objectives (move to alternate positions, complete defensive preparations, time to destroy enemy weapons).
- 2-1-2-8 SME observations on utilization of AGS and M551A1 in support of offensive operations.

MOE 2-1-3 Difference in the AGS unit's probability of mission success compared to that of the M551A1 in support of infantry MOUT operations.

- * 2-1-3-1...5 same as for MOE 2-1-1
- 2-1-3-6 Median time to meet mission objectives.
- * 2-1-3-7 Rate of advance.
- 2-1-2-8 SME observations on use of AGS and M551A1 in support of MOUT operations.

MOE 2-1-4 Difference in the AGS unit's probability of mission success compared to that of the M551A1 in support of infantry forced entry operations.

Not directly tested. Analysis based upon MOE 1-2-1, 2-1-1, and 2-1-2.

MOE 2-2-1 Difference in the proportion of correct identifications by the AGS compared to that of the M551A1.

- 2-2-1-1 Proportion of correct identifications given targets presented.
- 2-2-1-2 Percent of incorrect identifications.

MOE 2-2-2 Difference in the proportion of AGS acquisitions compared to that of the M551A1.

- 2-2-2-1 Median time for first acquisition.
- 2-2-2-2 Median range of first acquisition.
- 2-2-2-3 Median time for subsequent acquisitions.
- 2-2-2-4 Median range of subsequent acquisition.
- 2-2-2-5 Proportion of acquisitions given targets presented.
- * 2-2-2-6 Percent of acquisitions called out by crew when target did not exist.

MOE 2-2-3 Difference in the proportion of AGS engagements compared to that of the M551A1.

- 2-2-3-1...4 same as for MOE 2-2-2
- 2-2-3-5 Proportion of targets engaged given targets presented.
- 2-2-3-6 Proportion of targets engaged given targets acquired.
- 2-2-3-7 Engagement time.

MOE 2-2-4 Difference in the proportion of AGS hits compared to that of the M551A1.

- 2-2-4-1 Proportion of hits given engagement.
- 2-2-4-2 Proportion of hits given presentation.
- 2-2-4-3 Median time and range of hits.
- * 2-2-4-4 Proportion of kills given a hit.
- 2-2-4-5 Proportion of kills given a shot.

MOE 2-2-5 Contribution of the AGS design to its lethality.

[Note - addresses SMI]

- 2-2-5-1 Median time for crew to transfer 21 rounds to "ready to load" (standard 15 min).
- 2-2-5-2 Median time for crew to transfer remaining rounds to "readily accessible" status (standard 15 min).
- 2-2-5-3 Median time for gunner to load main gun when autoloader fails. (standard is 3 rnds/min)
- 2-2-5-4 Increase in engagement time caused by crew having to manually insert range adjustments if automatic system fails.

MOE 2-2-6 Ability of the system automation to enhance fightability of the AGS and be usable by soldiers of the required percentile.

[Note - addresses SMI]

- 2-2-6-1 Engagement sequence times of the AGS and M551A1 (from gunnery only).
- 2-2-6-2 Contribution of automation to AGS usability as measured through MANPRINT questionnaires.

MOE 2-3-1 Difference in the AGS probability of engaging and being engaged compared to that of the M551A1. (Concerns unique signatures AGS and M551A1)

- 2-3-1-1 Proportion of engagements given detection, given a hit and kill.

2-3-1-2 Median times to first and subsequent detection and engagement, given a hit and kill.

2-3-1-3 Median ranges of detection and engagement, given a hit and kill.

2-3-1-4 Median duration or time of red tracking (SAGGERS) of AGS and M551A1, given a hit and a kill.

2-3-1-5 AGS Developmental Test results of visual and aural cues.

MOE 2-3-2 Difference in AGS mobility compared to that of the M551A1.

[Note - addresses SMI]

2-3-2-1 Vehicle handling rating (crew).

2-3-2-2 SME comments on mobility restrictions.

MOE 2-3-3 Contribution of the AGS automation enhancements to the survivability of the AGS.

[Note - addresses SMI]

2-3-3-1 Ability of systems dependent on automation to function after LVAD, main gun firing and shock and or vibration due to ballistic shock.

2-3-3-2 Automation failures by component that occur in a tactical Radio Frequency Interference/Electromagnetic Interference (RFI/EMI) environment.

Issue 3. Is the AGS equipped unit operationally suitable and sustainable?

MOE 3-1-1 Single mission reliability greater than or equal to 90 percent.

3-1-1-1 Probability of completing a single mission.

3-1-1-2 Percent of test missions completed.

3-1-1-3 Percent of operating time the AGS is degraded.

MOE 3-1-2 AGS operational availability (A_0) greater than the M551A1 Sheridan operational availability.

3-1-2-1 Test operational availability.

3-1-2-2 Operational availability using the Reliability, Availability, Maintainability (RAM) Rational Report ALDT (administrative and logistics down time).

3-1-2-3 AGS operational readiness (OR) of at least 90 percent.

3-1-2-4 Achieved Availability.

MOE 3-1-3 Mean miles between mission aborts (MMBMA) greater than or equal to 230 miles.

3-1-3-1 Mean miles between mission affecting failure (MMBMAF) greater than or equal to 100 miles.

3-1-3-2 Mean miles between unscheduled maintenance actions.

3-1-3-3 Mean rounds between unscheduled maintenance actions.

3-1-3-4 Mean times between unscheduled maintenance actions.

MOE 3-1-4 Maintenance ratio less than or equal to 0.17 manhours per operating mile.

3-1-4-1 Maintenance ratio at each maintenance level.

3-1-4-2 Mean time to repair at each maintenance level.

3-1-4-3 Maximum time to repair.

3-1-4-4 Mean time required for pre-operation checks (NTE 1-hour).

3-1-4-5 Mean time required for post operation checks (NTE 1-hour).

3-1-4-6 Mean time required for pre-combat checks (NTE 20 minutes).

MOE 3-1-5 Fault isolation rate to the line replaceable unit (LRU) for detectable maintenance problems.

3-1-5-1 Percent of detectable maintenance actions detected using internal and external diagnostics.

3-1-5-2 Percent of detectable maintenance actions isolated to single LRU level using internal and external diagnostics.

3-1-5-3 Percent of detectable maintenance actions isolated to a single LRU level using only internal diagnostics.

3-1-5-4 No evidence of fault rate (NTE 3%).

3-1-5-5 Built-in-test equipment (BITE) false alarm rate.

MOE 3-1-6 Ability of the AGS automated internal diagnostics to correctly identify problems and restore functions as problems occur.

3-1-6-1 Mean time between mission affecting failures and software.

3-1-6-2 Mean time between priority 1 and 2 software faults.

* 3-1-6-3 Mean time between loss of function.

* 3-1-6-4 Percentage of automation problems resolved by user.

* 3-1-6-5 Mean time to restore a lost function.

MOE 3-2-1 Amount of change in equipment required to maintain the AGS from the M551A1 Sheridan.

3-2-1-1 Number of UMA which could not be corrected due to a lack of equipment.

3-2-1-2 Number and type of special tools and or equipment required to support and maintain the AGS.

3-2-1-3 Change in tools, equipment and facilities required to support and maintain the AGS.

3-2-1-4 Ability to accept standard NATO refueling nozzles.

MOE 3-2-2 Amount of change or in supply support or provisioning required to sustain the AGS from the M551A1 Sheridan.

3-2-2-1 Gallons of fuel consumed per operating mile.

3-2-2-2 Average time to rearm and refuel (NTE 15 minutes).

3-2-2-3 Average number rounds of ammunition consumed by type of mission and day.

3-2-2-4 Demand Satisfaction Index (DSI).

3-2-2-5 Percent of total ALDT hours due to lack of spare parts.

3-2-2-6 Accuracy and completeness of TMs.

MOE 3-2-3 AGS compatibility with rail, sea, and highway transport. To be addressed during MTMC study and not during EUTE.

3-2-3-1 AGS compatibility with CONUS and European rail equipment.

3-2-3-2 AGS compatibility with current sealift equipment.

3-2-3-3 AGS compatibility with marine hovercraft.

3-2-3-4 AGS compatibility with current Army and civilian heavy lift transporters.

MOE 3-2-4 Ability of AGS automated functions to be supported. Not evaluated during EUTE.

3-2-4-1 The software shall be developed IAW DoD Std 2167A.

3-2-4-2 The PDSS (Post Deployment Software Support) plan analysis will be conducted IAW DA Pam 71-3 and MIL Handbook 347.

MOE 3-2-5 Ability to transport AGS unique tools and special equipment without additional transportation or support assets.

3-2-5-1 Number of vehicles in excess of M551A1 unit TOE required to move AGS tools or equipment.

3-2-5-2 Record of additional support equipment in excess of M551A1 unit TOE required to support AGS tools or equipment (i.e., generators, etc.)

3-2-5-3 Percent of on-vehicle stowage of all on-board vehicle equipment (OVE) vehicle equipment and mission essential personal gear.

3-2-5-4 Ability to internally stow all mission essential personal gear

MOE 3-2-6 Compatibility of the AGS with current and future diagnostics equipment.

3-2-6-1 Ability of STE/ICE-R to interface and operate with AGS internal diagnostic systems.

3-2-6-2 Ability of Integrated Family of Test Equipment (IFTE) Contact Test Set (CTS) to interface and operate with AGS internal diagnostic systems.

3-2-6-3 Use of C-ATLAS for Test Program Set (TPS) software.

MOE 3-3-1 Mean time required to remove and replace the propulsion system. (Tested during EUTE only if it is necessary to perform maintenance. Event will be timed and number of people and tools required recorded.)

3-3-1-1 Percent of removal and replacement times exceeding 2 hours.

3-3-1-2 Number personnel required to remove and replace propulsion system.

MOE 3-4-1 Ability of the AGS to recover and tow another AGS to the task force supply route or maintenance collection point for collection. (Tested primarily during technical testing.)

3-4-1-1 Percent and number of successful towings by AGS or other TOE equipment.

3-4-1-2 Percent and number of successful recoveries by AGS or other TOE equipment.

3-4-1-3 Average time required for recovery operations.

3-4-1-4 Conditions for which AGS or TOE vehicles and or equipment were inadequate.

3-4-1-5 Average speed of towing operations.

MOE 3-5-1 Mean time for the AGS crew to install add-on armor (up to level 3).

3-5-1-1 Mean and median time required to install each level of armor (NTE 3 hours).

3-5-1-2 Average number of personnel required by skill level and Military Occupational Specialty (MOS) to install each level of add-on armor.

Issue 4. Are the MANPRINT characteristics involved in operation, maintenance and support of the AGS acceptable for training and operational settings?

MOE 4-1-1 Extent to which systems design features interfere with the ability of representative soldiers to operate, maintain and support the AGS effectively in an operational setting.

* 4-1-1-1 Number of missed target engagements due to inadequate human factor engineering (HFE) design.

- * 4-1-1-2 Number of fratricides due to inadequate HFE design.
- 4-1-1-3 Number of RAM incidents due to inadequate HFE design.
- * 4-1-1-4 List of logistics incidents, by type, due to inadequate HFE design.
- 4-1-1-5 List of maintenance incidents, whether or not a TIR (Test Incident Report) was written or not, due to inadequate HFE design.
- 4-1-1-6 List of operator incidents, by type, due to inadequate HFE design.
- * 4-1-1-7 Number of missed or incorrect target identifications due to inadequate HFE design.

MOE 4-2-1 Extent to which aptitudes, experience and skill levels possessed by the test player MOS population are sufficient to operate, maintain and support the AGS effectively in an operational setting.

- * 4-2-1-1 Number of missed target engagements due to inadequate personnel profile.
- * 4-2-1-2 Number of fratricides due to inadequate personnel profile.
- * 4-2-1-3 Number of RAM incidents due to inadequate personnel profile.
- 4-2-1-4 List of logistics incidents, by type, due to inadequate personnel profile.
- 4-2-1-5 List of maintenance incidents, whether or not a TIR was written or not, due to inadequate personnel profile.
- 4-2-1-6 List of operator incidents, by type, due to inadequate personnel profile.
- * 4-2-1-7 Number of missed or incorrect target identifications due to inadequate personnel profile.

MOE 4-3-1 Adequacy of numbers of personnel in sections outlined in the AGS TOE to effectively operate, maintain and support the AGS.

- * 4-3-1-1 Number of missed target engagements due to inadequate manpower problems.
- * 4-3-1-2 Number of fratricides due to inadequate manpower problems.
- * 4-3-1-3 Number of RAM incidents due to inadequate manpower problems.
- 4-3-1-4 List of logistics incidents, by type, due to manpower problems.
- 4-3-1-5 List of maintenance incidents, whether or not a TIR was written or not, due to manpower problems.
- 4-3-1-6 List of operator incidents, by type, due to manpower problems.
- * 4-3-1-7 Number of missed or incorrect target identifications due to manpower problems.

MOE 4-4-1 List of new safety hazards, or enhancement of an identified one's severity or probability beyond the acceptable level of risk created by the operation or maintenance the AGS.

- 4-4-1-1 The number, type and description of safety items identified in the System Safety Release (SSR).
- 4-4-1-2 The number, type and description of safety items observed during the operational test on the AGS operation, maintenance and support on AGS.

MOE 4-4-2 List of new health hazards, or enhancement of an identified one's severity or probability beyond the acceptable level of risk created by the operation or maintenance the AGS.

- 4-4-2-1 The number, type and description of health items identified in the System Safety Release (SSR).
- 4-4-2-2 The number, type and description of health items observed during the operational test on the AGS operation, maintenance and support on AGS.

MOE 4-5-1 Extent to which typical target MOS soldiers were trained to operate, maintain and support the operational environment under normal and degraded system operating modes.

- * 4-5-1-1 Number of missed target engagements due to inadequate training.
- * 4-5-1-2 Number of fratricides due to inadequate inadequate training.
- 4-5-1-3 Number of RAM incidents due to inadequate inadequate training.
- 4-5-1-4 List of logistics incidents, by type, due to inadequate training.
- 4-5-1-5 List of maintenance incidents, whether or not a TIR was written or not, due to inadequate training.
- 4-5-1-6 Number of missed or incorrect target identifications due to inadequate training.
- 4-5-1-7 List of operator incidents, by type, due to inadequate training.
- 4-5-1-8 List of test player end of NET and collective training comments on the adequacy of the training system to enable them to perform all tasks required to operate, maintain, and support the AGS.

MOE 4-6-1 The AGS system design must allow expedient crew ingress, egress and evacuation in all levels of armor and all levels of protective clothing and all aspect angles. Timed data collected during User Jury will be used to address this MOE. Ingress, egress, and evacuation will be addressed through MANPRINT questionnaires.

- 4-6-1-1 Time for crew to completely ingress in level 1, 2, and 3 armor in MOPP 0 through MOPP 4.
- 4-6-1-2 Time for crew to completely egress in level 1, 2, and 3 armor in MOPP 0 through MOPP 4.
- 4-6-1-3 Time for crew to completely egress in level 1, 2, and 3 armor in MOPP 0 through MOPP 4 while evacuating simulated injured driver internally through the gunner station.

Issue 5. **Does the AGS communications equipment effectively support command and control mission requirements?**

MOE 5-1-1 Ability of the equipment to maintain communications between the AGS commander and driver to support effective vehicle and unit movement?

- * 5-1-1-1 Percent of orders clarification requested due to equipment problems.
- 5-1-1-2 Percent of movements executed as ordered.

MOE 5-1-2 Ability of the equipment to maintain communications between the crew needed to support effective employment of the AGS vehicle and unit (gunnery only)?

- * 5-1-1-1 Percent of orders clarification requested due to communication equipment problems by mission and crew pairing.
- 5-1-1-2 Soldier median rating of procedures and performance of internal communications associated tasks.

MOE 5-2-1 Ability of the equipment to maintain communications between the AGS and M551A1 and other elements to support mission accomplishment.

- * 5-2-1-1 Percent of orders clarification requested due to communication equipment problems by pairing.
- * 5-2-1-2 Percent successful transmissions by pairing.
- * 5-2-1-3 Percent of missions not executed successfully due to communications equipment problems.

MOE 5-2-2 Ability of the external phone to enable communications between dismounted infantry and the AGS crew.

- * 5-2-2-1 Number of unsuccessful transmissions using the external phone
- * 5-2-2-2 Number of times external phone use interfered with internal communications.
- 5-2-2-3 Soldier median rating of procedures and performance of external phone associated tasks.

MOE 5-2-3 Ability of the AGS to operate as part of a hot-loop configuration.

- * 5-2-3-1 Percent of unsuccessful transmissions.
- * 5-2-3-2 Number of times internal and external communications interfered with while operating as a hot-loop.

MOE 5-3-1 Impact of electro-magnetic interference (EMI) from other AGS operating systems or outside operating systems on the functioning of AGS C3 systems. (Tested during Technical Testing).

- 5-3-1-1 Percent of unsuccessful transmissions due to internal and external sources of EMI.
- 5-3-1-2 Source of interference and range from AGS.
- 5-3-1-3 List of incidents occurring when operating in a degraded mode due to EMI.

Issue 6. Can the crew operate the AGS effectively in MOPP 0-4?

MOE 6-1-1 Difference in the AGS crew's ability to fire all weapons in varying levels of MOPP versus acceptable standards.

- 6-1-1-1 Difference from standards as outlined in FM 17-12-XX for vehicle table VIII (main gun, coax, and machine gun).

MOE 6-1-2 Difference in the AGS crew's ability to operate all communications equipment in varying levels of MOPP versus acceptable standards.

- 6-1-2-1 Differences from standards as for drivers tasks as defined in the Gunnery Skills Test.
- 6-1-2-2 Differences from standards as for commander and gunner tasks as defined in the Gunnery Skills Test.

MOE 6-1-3 Difference in the AGS crew's ability to operate and maintain (PMCS) in varying levels of MOPP versus acceptable standards.

Note- Motor Pool Environment

- 6-1-3-1 Differences from standards in performance of the Prepare for Fire checklist.
- 6-1-3-2 Differences from standards in performance of the prep-to-fire checklist.
- 6-1-3-3 Differences from standards in performance of the pre-fire checklist.

MOE 6-1-4 Ability of the AGS design to support effective operations in an NBC environment.

- 6-1-4-1 Number of incidents and circumstances when crew could not meet mission performance measures due to constraints of wearing MOPP equipment.

6-1-4-1 Number of incidents, human versus equipment, that impact crew performance during extended operations in an NBC environment.

APPENDIX C

Key Human Dimension Questions Identified in the AGS SMMP

Issue: Ability of soldiers from the target audience to operate, maintain, repair, and support the system to prescribed performance standards in all uniforms and under all environmental conditions.

- Are there increases in physical or cognitive requirements for operators, maintainers, repairers and supports?
- What are the physical requirements placed upon the gunner and commander if he has to manually load the main gun? How long can he load the main gun to prescribed performance standards during sustained operations?
- Will enclosed (buttoned up) operations be required? If so, what provisions have been made to enhance operations, i.e., resting, general crew comfort, bodily function relief/discharge, etc?
- Are manual backup systems designed to minimize labor intensity and reduce fatigue?
- During 96 hour sustained and/or continuous operations mission scenario can the crew operate the AGS to prescribed performance standards? If not, can improvements in the system design alleviate this problem?
- Can the main weapon system be operated by the crew with an inoperative autoloader and still achieve the required rate of three rounds per minute, having to manually index the autoloader and manually load the main gun?

Issue: Impacts of crew reduction (mission performance during sustained operations and degraded mode operations).

- Can the AGS crew continue to operate over extended periods after losses of personnel and/or subsystems? Can a reduced crew still meet the 96 hour continuous operation requirement? For how long? At what level?
- What is the impact of the reduced crew size on manual firing of the main gun, this includes both a three and two man crew?
- Has the workload been distributed equally among the crew?
- Is the crew size (3) large enough to sustain continuous operations for 96 hours?

Issue: Identification of structure, manpower requirements, personnel requirements and impacts of a 3-man crew on the armored vehicle crewman career management field (CMF 19) grade structure.

- Will there be a requirement for the crew to perform dismounted tactical security operations. If so, how will they do this?

Issue: Effectiveness of the system after loss of subsystem components or personnel.

- Can the system be operated after a loss of one or more crewman? If so, what is the resulting level of degradation?

- Can the system be operated after the loss of subsystem and components? If so, which components? What is the resulting level of degradation?

ENDNOTES

¹This includes personnel costs. Myrna Z. Kroh, Armored Gun System, (White Sands Missile Range, New Mexico: U.S. Army TRADOC Systems Analysis Activity, 1985), p. 2.

²Gary L. Moore, "Is a Turretless Tank a Viable Option for the United States Army?" Thesis, Master of Military Art and Science, (Fort Leavenworth, Kansas: US Army Command and General Staff College, 1990), p. 165.

³Randall Steeb, et al., An Exploration of Integrated Ground Weapons Concepts for Armor/Anti-Armor Missions, (Santa Monica, California: RAND Corporation, 1991), p. 150.

⁴Phillip W. Lett, "Type 90 Tank a Milestone for Japanese Industry," International Defense Review, No. 6/91, p.631.

⁵U.S. Department of the Army, Soldier Performance in Continuous Operations, Field Manual 22-9, (Washington, D.C.: U.S. Government Printing Office, 1991), Glossary

⁶Ibid, p.v.

⁷Based upon the author's personal experiences in OPERATION DESERT STORM, once units deployed into tactical assembly areas in northern Saudi Arabia, they maintained around-the-clock security. Units in 1st Battalion, 34th Armor, 1st Infantry Division deployed to the division assembly area, TAA Roosevelt, beginning the week before the commencement of combat operations in the theater on 17 January 1994. They maintained around-the-clock operations until 24 February when they transitioned to CONOPS with the start of the ground war. The last two days of combat, from the morning of 26 February until the suspension of hostilities on the morning of 28 February, were SUSOPS. From 1 March until 20 April, the unit conducted around-the-clock operations while occupying positions in Kuwait and Iraq.

⁸Jeff Parks, Main Battle Tank Crew Task List, (Warren, Michigan: U.S. Army Tank-Automotive Command, 1987), p. 5.

⁹As noted in the introduction, the French are currently fielding the 3-man-crew Leclerc. The Japanese have the Type-90 tank in development, also with a 3-man-crew.

¹⁰Parks, pp. 7-8.

¹¹Operate the elevation uncouple is a task which is already largely automated. The elevation uncouple brings the gun tube to zero elevation (level) to allow the loader to load the round. This occurs automatically when the gun safe arm is in the SAFE position. When the loader has loaded a round, he moves the gun safe arm to the ARM position and announces "UP" This disengages the elevation uncouple and indicates the main gun is loaded and ready to fire. This sequence would obviously be automated if the tank were equipped with an autoloader.

¹²These are two subtasks under the task, prepare the loader's station for operation. There are other related tasks in the area of communication. An argument might be made to automate turning on the amplifier and radio as part of powering up the vehicle.

¹³Units carried an additional 10,000 rounds on each tank during DESERT STORM for immediate resupply. It was not "broken down," that is, taken out of the boxes and linked.

¹⁴The loader's weapon is the M240 Machine gun. It is identical to the coax the gunner fires. The loader's machine gun serves as a replacement weapon should the coax become inoperative in addition to providing an additional anti-personnel capability.

¹⁵Richard Simpkin, Tank Warfare, (London: Brassey's Publishers Limited, 1979), p. 125.

¹⁶IVIS is a distributed information management system designed to improve situational awareness, orders distribution, obstacle bypass efficiency, and reporting. It is being fielded in the M1A2 and is part of the Combat Vehicle Command and Control System (CVC²) now under development. Bruce C. Leibrecht, et al, Combat Vehicle Command and Control Systems: I. Simulation-Based Company Evaluation, (Fort Knox, Kentucky: BDM International, Inc., 1992), pp. 7-8.

¹⁷Ralph Zumbro, Tank Sergeant, (Navato, California: Presidio Press, 1986), p. 80.

¹⁸Leader tanks currently have an AN/VRC 12 radio installed. Ten channels can be pre-set on it and then the tank commander can operate it remotely from his position on the tank. If the radio fails to switch to the correct frequency, the loader must manually tune the radio to the correct frequency.

¹⁹LP/OP - Listening Post/Observation Post is a task which usually involves dismounting soldiers to a position away from the vehicles to observe or listen for approaching enemy. This allows the vehicles to remain in a concealed position until they are required to fight or maneuver.

²⁰Simpkin, p. 152.

²¹Ibid, p. 125 and 151. See also: Robin Fletcher, "Main Battle Tank Crew Reduction," International Defense Review, No. 1/87, pp. 69-74 and "The Two Man Tank - Its Fightability and Endurance," Armor, (November-December 1992), p. 36; Mike Newell, "Survivability is the Best Argument for a Two-Man Tank," Armor, (March-April 1992), p. 20; and John C. Woznick, "Developing a Tank Autoloader," Armor, (September-October 1989), p. 11.

²²Martin van Creveld, Technology and War, (New York: The Free Press, 1989), pp. 316-318.

²³U.S. Department of the Army, Operations, Field Manual 100-5, (Washington, D.C.: U.S. Government Printing Office, 1993), pp. 2-6 to 2-9.

²⁴Four companies each with:
6 tanks - Platoon leader and platoon sergeant in each platoon (3 platoons per company)
2 tanks - Company commander and executive officer tanks.
The battalion commander and S3/executive officer also have tanks.

²⁵Simpkin, p. 152.

²⁶FM 17-15 Tank Platoon
FM 71-1 The Tank and Mechanized Infantry Company Team
FM 71-2 The Tank and Mechanized Infantry Battalion Task Force
FM 71-123 Tactics and Techniques for Combined Arms Heavy Forces: Armored Brigade, Battalion/Task Force, and Company Team
ARTEP 17-237-10-MPT Mission Training Plan for the Tank Platoon
ARTEP 71-1-MPT Mission Training Plan for the Tank and Mechanized Infantry Company Team
ARTEP 71-2-MPT Mission Training Plan for the Tank and Mechanized Infantry Battalion Task Force
ST 17-17 Combined Arms Heavy Battalion/Task Force SOP
ST 100-3 Battle Book.

²⁷Hans von Seeckt, Thoughts of a Soldier, (London: Ernest Benn Limited, 1930), p. 59.

²⁸Lon E. Maggart, "Advanced Warfighting Experiment," Army Research, Development and Acquisition Bulletin, (November-December 1994), p. 12.

²⁹Based upon the author's five years of personal experience operating at company level and below without digitization, the loader acting as the TC while the TC, in the loader's position, commands the unit is not a new or uncommon solution to the problem of commanding both the vehicle and a unit.

³⁰Mounted Warfighting Battlespace Lab, Advanced Warfighting Experiment, OPERATION DESERT HAMMER VI Final Report, (Ft. Knox, Kentucky: United States Armor Center, July 28, 1994), p. Issues: Soldiers - 4.

³¹Ibid.

³²Maggart, p. 13.

³³Currently, 50% security, one half of the crew awake while one half of the crew sleeps is a common level of security. 25% security involves one man awake.

³⁴Fletcher, "Main Battle Tank Crew Reduction," p. 69 and J.B. Gilvydis, "A Future U.S. Main Battle Tank for the Year 2010 - A New Vision," Armor, (May-June 1994), p. 9. Gilvydis, with 33 years experience at TARDEC working on the design and engineering

of combat vehicle systems, expresses almost disbelief that crews operate for extended periods of time "up to some 72 hours at times. . . [which] tires a crew and renders the tank ineffective."

³⁵Simpkin, p. 125.

³⁶FM 22-9, pp. 2-3.

³⁷Timothy J. O'Keefe, Kerm Henriksen, and Jacob L. Barber, Human Performance Data Relevant to the Armored Family of Vehicles (Alexandria, Virginia: Allen Corporation of America, 1990), p. 18.

³⁸Patrick A. Stallings, "Tank Company Security Operations," Armor, (November-December 1992), p. 20.

³⁹Newell, p. 21 and Dr. Kathleen A. Quinkert, Army Research Institute, Telephonic Interview, Fort Knox, Kentucky, 9 October 1994.

⁴⁰"New Information on France's Latest MBT," International Defense Review, No. 3/87, p. 267.

⁴¹COL Bertrand Maupoume', French Army Liaison Officer to Ft. Leavenworth, Personal Interview, Ft. Leavenworth, Kansas, 22 August 1994.

⁴²U.S. Department of the Army, Manpower and Personnel Integration (MANPRINT) in the Material Acquisition Process, Army Regulation 606-2, (Washington, D.C.: U.S. Government Printing Office, 1990), p. 3.

⁴³Formerly Human Engineering Laboratory (HEL)

⁴⁴O'Keefe, et al, p. 28.

⁴⁵Harold R. Booher and Glen M. Hewitt, "MANPRINT Tools and Techniques," in MANPRINT: An Approach to Systems Integration, ed. Harold R. Booher, (New York: Van Nostrand Reinhold, 1990), pp. 352-364.

⁴⁶John W. Ruffner, A Study of Human Factors Methodologies and Models for Improving the Maintainability of Emerging Army Aviation Systems, (Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences, 1990), p. 44.

⁴⁷Ronald H. Lafond and Scott Marshall, HARDMAN III Utility Assessment Analysis, (Rockville, Maryland: AEPCO, Inc., 1993), p. v.

⁴⁸Larry W. Avery, Human Factors and Safety Assessment of Army Systems, (Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences, 1989), pp. 26 and 29.

⁴⁹Kathleen A. Quinkert, Crew Performance Associated with the Simulation of the Commander's Independent Thermal Viewer (CITV), (Alexandria, Virginia: U.S. Army Research Institute for the Behavioral and Social Sciences, 1990), p. 9.

⁵⁰US General Accounting Office, "The Army can better integrate manpower, personnel, and training into the weapon systems acquisition process," (September 27, 1985), as quoted in Harold E. Price, "Conceptual System Design and the Human Role," in MANPRINT: An Approach to Systems Integration, ed. Harold R. Booher, (New York: Van Nostrand Reinhold, 1990), pp. 169-170.

⁵¹Sergej Gryankin, "The T-54," Tekhnika - Molodezhi, 2/90, pp. 12-13.

⁵²Sergej Gryankin, "The T-44," Tekhnika - Molodezhi, 1/90, pp. 22-23.

⁵³Gryankin, "The T-54, pp. 12-13.

⁵⁴S. Maev, "Combat Readiness: The Parameters of Quality 'Armor is Strength. But For What?" Tyl Vooruzhenikh Sil, 10/90, pp. 36-38.

See also - Lieutenant General of Medical Service P. Vyazitskij, Professor and Doctor of Medical Science, Colonel of Medical Service I. Kudrin, Professor and Doctor of Medical Science, Colonel of Medical Service M. D'yakonov, Doctor of Medical Science, and Colonel M. Tikhonov, "When the Man is Forgotten." Voennyi Vestnik, 4/91, pp. 14-17. The article notes "... it means that quite often we build into those very vehicles and systems an adaptability that makes them function in spite of the physical and psychological abilities of the men inside them. . . It's not difficult to see that when the man is brought into consideration he 'falls out,' or in the vernacular, he is treated much as a fifth wheel on a wagon. . . It just seems that when the designers come up with the finished product they forget all about the abilities and the needs of the human organism"

⁵⁵AR 602-2, p. 4.

⁵⁶Those issues were: Training impacts
Identification and elimination or reduction of safety and health hazards.

⁵⁷XM8 Armored Gun System (AGS) System MANPRINT Management Plan (SMMP) in Support of MDR III. unsigned. 6 February 1993, updated as of 22 August 1993. pp. 4-10.

⁵⁸Constraint: restrict freedom of action for planning a mission by stating what must be done. FM 100-5, p. Glossary-2.

⁵⁹AGS SMMP, p. 7.

⁶⁰Ibid, pp. 14-36.

⁶¹Crew reduction issues: the implications of operating the AGS with a three-man crew, a degraded crew or a degraded vehicle.

⁶²AGS SMMP, p. 6.

⁶³Mr. John Phillips, Program Executive Officer, Project Manager-Armored Gun System (PM-AGS), E-Mail Interview, Warren, Michigan, 10 January 1995.

⁶⁴Per AR 602-2, paragraphs 2-6 a and h, pp. 5-6, the DCSPER exercises primary Department of the Army (DA) staff responsibility for the MANPRINT program and approves DA policy, guidance and formats for all MANPRINT related documents, including the SMMP.

⁶⁵Assessment ratings definitions:

GREEN - No problems. All actions on schedule.

AMBER - Significant or minor problems identified, with a solution or work-around plan expected to be completed by the next major milestone date.

RED - Significant problems with no solution identified or solution being implemented with less than satisfactory results projected by the next major milestone date. U.S. Department of the Army, Integrated Logistic Support, Army Regulation 700-127, w/change 2, (Washington, D.C.: U.S. Government Printing Office, 1990), p. 49.

⁶⁶**Fightability** is defined as the ability to execute mission tasks per the published Mission Training Plan IAW published tactics, techniques and procedures (TTP) for the AGS equipped unit. **Usability** is not defined. MG Jay M. Gardner, Assistant Deputy Chief of Staff for Operations and Plans, Force Development, MEMORANDUM FOR Chairman, Armored Gun System (AGS) Test Integration Working Group (TIWG), Warren Michigan. Subject: Critical Operational Issues and Criteria (COIC) for the Armored Gun System, dtd 25 FEB 1992, p. 2. in TSM-AGS, Armored Gun System (AGS) Test & Evaluation Master Plan (TEMP), with cover memorandum, Subject: SAB, From Walter W. Hollis, Deputy Under Secretary of the Army, dtd. 5 October 1992, (Fort Knox, Kentucky: U.S. Army Armor Center and Fort Knox, July 1992)

⁶⁷TSM-AGS, Test Design, p. 3-38

⁶⁸IVIS is a programmed upgrade for the AGS system. It is significant to note that nothing in the EUTE addressed this aspect of command and control. The operation of IVIS by a three man crew is a significant issue which eventually must be addressed. Essentially, no considerations are being made for its future installation during this phase of development. This could prove to be a costly improvement especially if components must be moved or redesigned to accommodate interoperability with the crew. This issue relates directly to the GAO findings regarding life cycle costs and commitment of funds.

⁶⁹MOPP - Mission oriented protective posture

⁷⁰TSM-AGS, Test Design, Chapter 3.

⁷¹In the E-Mail interview Mr. Phillips writes, "You've [the author] implied that a three man crew is a critical issue for the AGS and it is not being tested. I don't think I agree and here is why. What AGS is required to do operationally is outlined in the requirements document (ROC, now ORD [operational requirements document]). AGS or any system has to be tested to see if it is operationally capable and suitable. So, as in the case of the AGS (even though I care from a Manprint perspective) we don't go out and see if the three man crew can do their job today, we see if AGS can do [sic] perform all of its critical and secondary mission requirements regardless of what any specific design or other characteristic might be. So if when we test AGS to see if it can perform its forced insertion mission, if it does well - great! if it doesn't then we need to determine what why not and what it takes to remedy the situation - whether it be hardware, training, software, support, too much cognitive demand on one crew member or whatever.

In other words we're buying an AGS to meet mission requirements that are being evaluated. We're not buying the Army's three man test bed that is intended to prove out three vs. four man crews vs. two man crews are optimal or suitable."

⁷²U-COFT is a high fidelity tank simulator developed for the US Army to meet the need for a M1 gunnery trainer. U-COFT allows tank commanders and gunners to train and sustain gunnery proficiency by performing gunnery tasks under simulated combat conditions. The U-COFT can simulate offensive and defensive, day and night situations under varied weather conditions, with varied levels of enemy contact, in a chemical or non-NBC environment, with a fully operational or degraded system ranging from minor malfunctions through incrementally more complex malfunctions to complete failure requiring manual operation of the fire control system.

⁷³SIMNET-D is used for evaluation of advanced doctrine and combat development systems. It has reconfigurable crew spaces, making it possible to emulate novel combat systems in development. The training version, SIMNET-T, has up to 200 individual Bradley Fighting Vehicle and M1 tank full-crew simulators and a central control center which provide realistic tactical training for large armored units. Units may maneuver and exercise their skills and tactics in simulated battles via a computer network connecting the simulators. Source - Richard W. Pew, et al, ARI V(INT)2 Soldier Machine Interface Demonstrator: Results of Experimentation on SIMNET-D, (Cambridge, Massachusetts: BBN Laboratory, Inc., 1989), p. 7.

⁷⁴Quinkert, p. 9.

⁷⁵Ibid, p. 33.

⁷⁶The systems were the position navigation (POSNAV) system which provides vehicle location and facilitates maneuver, a digital command and control display (CCD) (IVIS-based), and the CITV.

⁷⁷Frances M. Ainslie, Bruce C. Leibrecht, and Nancy K. Atwood, Combat Vehicle Command and Control Systems: III. Simulation-Based Company Evaluation of the Soldier-Machine Interface (SMI), (Fort Knox, Kentucky: BDM International, Inc., 1991), pp. 7-12.

⁷⁸Ibid, pp. 66-74.

⁷⁹John C. Woznick, "Developing a Tank Autoloader," Armor, (September-October 1989), pp. 13-15.

⁸⁰U.S. Army TARDEC, Crewman's Associate Advanced Technology Demonstration. Crew Task Automation Summary Document, Warren Michigan, July 1994, p. 1.

⁸¹Ibid.

⁸²A larger calibre gun than 120mm requires using a much larger and heavier gun trunion and breach assembly. This increases the vehicle weight, raises the vehicle profile and uses more space inside the turret to such an extent that a wider and taller turret might be required. If a larger calibre gun is used, an autoloader is required due to the larger round size. This is probably the most often used argument for adding an autoloader to the tank.

⁸³FMC Corporation, Ground Systems Division, Prime Item Development Specification for Armored Gun System, (Santa Clara, California: U.S. Army Tank-Automotive Command), 20 January 1993, p. 24.

⁸⁴This requirement is based upon achieving a qualifying score for a two enemy tank engagement in either the offense or defense. The crew would have to have the best possible opening and hit time for the first tank. If hitting the first tank takes longer than the fastest time, then the time allotted to hit the second tank is reduced and, correspondingly, so is the reloading time. Obviously, the task would be much more difficult in a moving tank than in a stationary one.

⁸⁵U.S. Department of the Army, Tank Combat Tables, Field Manual 17-12-1, with changes 1 and 2, (Washington, D.C.: U.S. Government Printing Office), 1988, pp. 11-119 - 11-124 and 11-128 - 11-133

⁸⁶U.S. Army TARDEC, p. 13.

⁸⁷Ibid, pp. 16-17.

⁸⁸Based upon the author's experience (which includes 29 months as the battalion maintenance officer in a USAEUR armor battalion), critical fire control component repair parts are not kept on hand because of their cost and sensitive nature. This includes thermal receiving units (TRU) for the thermal sight, computer control units (CCU), computer control panels, and lower gunner primary sight (GPS) panels. Additionally, electronics units (EU) and turret network boxes (TNB), which are critical to operating the tank automotively, are not maintained on hand for the same reason.

⁸⁹M1IP has a 105 mm gun system, no NBC system, and different automotive and fire control systems than the 120 mm M1A1 tank.

⁹⁰There is no information network linking armor and infantry battalions with their higher support unit, the forward support battalion. In the current armor battalion organization, the support platoon, which provides all Class III, IV, and V to armor companies, is only authorized one radio for more than 25 vehicles. The maintenance platoon is authorized no radios for requisitioning repair parts. Radios are authorized for only ten vehicles in the platoon. Only one of these vehicles operates in the battalion field trains area, doctrinally located at least 25 kilometers from the forward line of troops (FLOT). One third to one half of the platoon operates out of the field trains. The majority of the rest of the platoon is forward with the armor companies along the FLOT; the remainder operates out of the unit maintenance collection point 7-10 kilometers from the FLOT. The platoon is not authorized any equipment to increase the 6-10 km range of its radios.

⁹¹Soft system crashes occur when the equipment fails but data is saved or backed-up, allowing retrieval when the system is restarted or repaired, or allowing print-outs to be made and facilitating the use of a manual system.

⁹²U.S. Army TARDEC, pp. 2-6.

⁹³Ainslie, Leibrecht, and Atwood, pp. 14-25; Derek C. Schneider, "Combat Vehicle Command and Control," Armor, (July-August 1994), pp. 40-42; and U.S. Army TARDEC, pp. 2-6.

⁹⁴See Maggart, p. 13, Mounted Warfighting Battlespace Lab, p. Issues: Soldiers - 4, and Ainslie, Leibrecht, and Atwood, pp. 70-74.

⁹⁵U.S. Army TARDEC, p. 7.

⁹⁶Frank A. Briglia, "Vehicle Defense Today, Tomorrow, and Next Year." Armor, (July-August 1994), pp. 6-9.

⁹⁷U.S. Army TARDEC, pp. 6-13.

⁹⁸Van Creveld, p. 304.

⁹⁹Ibid.

¹⁰⁰GEN Gordon R. Sullivan, "Force XXI: Digitizing the Battlefield," Army Research, Development and Acquisition Bulletin, (November-December 1994), pp. 2-3.

¹⁰¹Van Creveld, p. 232 and Booher, pp. xii and 237-246.

¹⁰²Ainslie, Leibrecht, and Atwood, p. 3.

¹⁰³Simpkin, pp. 120-123

GLOSSARY

AGS - Armored Gun System
ALDT - Administrative and logistics down time
ARI - Army Research Institute
ARL - Army Research Laboratory
BII - Basic Issue Item
BITE - Built-in Test Equipment
BLUEFOR - blue forces (friendly)
C² - Command and Control
C³ - Command, Control, and Communications
CAATD - Crewman's Associate Advanced Technology Demonstration
CCD - Command and Control Display
CCU - Computer Control Unit
CITV - Commander's Independent Thermal Viewer
CMF 19- Armored Vehicle Crewman Career Management Field
COIC - Critical Operational Issues/Criteria
CONOPS - Continuous Operations
CONUS - Continental United States
CTS - Contact Test Set
CVC - Combat Vehicle Crewman
CVC² - Combat Vehicle Command and Control
DA - Department of the Army
dB - decibels
DCSPER - Deputy Chief of Staff for Personnel
DSI - Demand Satisfaction Index
EPW - Enemy Prisoner of War
EUTE - Early User Test and Evaluation
FLOT - Forward Line of Troops
FRH - Fluid Replenisher Hydraulic
HEL - Human Engineering Laboratory
HFE - Human Factors Engineering
HRED - Human Research and Engineering Directorate
IAW - In accordance with
IFTE - Integrated Family of Test Equipment

ILSMT - Integrated Logistic Support Management Team
IVIS - Intervehicular Information System
LP/OP - Listening Post/Observation Post
LRIP - Low Rate Initial Production
LRU - Line Replaceable Unit
LVAD - Low-Velocity Air Deliverable, Deployable, or Droppable
MANPRINT - Manpower and Personnel Integration
MBT - Main Battle Tank
MDR - Milestone Decision Review
MEF - Mission Essential Functions
METT-T - Mission, Enemy, Terrain, Friendly Troops Available, and Time
MMBMA - Mean miles between mission aborts
MMBMAF - Mean miles between mission affecting failure
MOE - Measure of Evaluation
MOPP - Mission oriented protective posture
MOS - Military Occupational Specialty
MPT - Manpower, Personnel, and Training
MSE - Mobile Subscriber Equipment
MWTB - Mounted Warfare Test Bed
MTMC - Materiel Traffic Management Command
NTE - Not to exceed
OPFOR - Opposing Forces (enemy)
OR - Operational Readiness
OVE - On-board Vehicle Equipment
PDSS - Post Deployment Software Support
PLL - Prescribed Load List
PM AGS - Project Manager AGS
POSNAV - Position Navigation System
PVS-2/5 - Night Vision Devices
RAM - Reliability, Availability, Maintainability
RFI/EMI - Radio Frequency Interference/Electromagnetic Interference
RO/RO - Roll on/Roll off
SAGGER - Threat wire guided, optically sighted Anti-tank weapon
SIMNET-D - Simulated Network - Developmental
SINGARS - Single Channel Ground Airborne Radio System
SMI - Soldier Machine Interface

SMMP - System MANPRINT Management Plan
SUSOPS - Sustained Operations
TAA - Tactical Assembly Area
TACOM - Tank Automotive Command
TAD - Target Audience Descriptors
TARDEC - Tank Automotive Research Development and Engineering Center
TEMP - Testing and Evaluation Master Plan
TF - Task Force
TIR - Test Incident Report
TM - Technical Manual
TNB - Turret Networks Box
TPS - Test Program Sets
TRADOC - Training and Doctrine Command
TRU - Thermal Receiving Unit
TSM AGS - TRADOC System Manager AGS
U-COFT - Unit-Conduct of Fire Trainer
UMA - Unit Maintenance Actions
USAEUR - US Army Europe
USAF - United States Air Force
VIDS - Vehicle Integrated Defense System

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